4. I-5 Test Evaluation

4.1 Objectives and Performance Measures

The evaluation of the surveillance and ramp meter trailers in support of freeway ramp metering had quantitative and qualitative objectives as listed in Table 4-1. Objectives 1 and 2 had quantitative and qualitative components, while Objectives 3 and 4 were qualitative.

Table 4-1. Linkage of I-5 Test objectives to quantitative and qualitative aspects of the evaluation

Objective	Test Type	Supporting Data	Where Discussed
1. Examine portability of the surveillance and ramp meter trailers	Quantitative	Measurements of trailer hitch, transport, set in place, and make operational times	Section 4.6.1
	Qualitative	Identify issues associated with selecting the evaluation sites and transporting the trailers	Section 4.6.1
2. Demonstrate satisfactory operation of the surveillance and ramp meter trailers at freeway locations where permanent traffic management systems are disabled	Quantitative	Comparisons of measured ILD and VIP traffic flow parameters output by 170 controllers	Section 4.6.2, 4.8, 4.9, 4.10
	Qualitative	Monitor reception of video and data; exercise camera pan, tilt, and zoom controls and trailer turnon, turnoff, and alarm functions	Section 4.6.2
3. Examine institutional issues, benefits, and costs associated with deploying surveillance and ramp meter trailers in a freeway setting	Qualitative	Interviews to seek critiques, suggestions, costs, and advantages and disadvantages of freeway trailer deployment	Section 4.6.3, 4.11
4. Examine institutional issues associated with sharing freeway video and data information among Caltrans, Anaheim, and the ITS Laboratory at UCI	Qualitative	Interviews to seek critiques, suggestions, and advantages and disadvantages of information sharing	Section 4.6.4

Objective 1 examined the portability of the surveillance and ramp meter trailers by (1) measuring the time to hitch, transport, set in place, and prepare the trailers for operation and (2) identifying the issues associated with deploying the trailers. The Anaheim Special Event Test had an identical objective.

Objective 2 also had quantitative and qualitative components. The quantitative portion determined how well the surveillance and ramp meter trailers met their intended goal of performing the ramp-metering function. It compared inductive loop detector (ILD) and video image processor (VIP) mainline and onramp traffic flow data. The traffic parameters measured by these sensors were processed by two 170 computers, one assigned to the ILD data and one to the VIP data. Laptop computers, connected to each of the 170 controllers through a serial port, recorded the processed data in 30-second intervals and, thus, simulated the data polling normally performed by computers at the TMC. Caltrans developed the data recording and analysis programs that facilitated the comparison of mainline lane occupancies and volumes, ramp signal demand, and ramp-metering rates computed from the ILD and VIP measurements.

The qualitative evaluation associated with Objective 2 occurred in the Caltrans District 12 and Anaheim TMCs and the ITS Laboratory at UCI. Personnel at these locations monitored the reception of video and data and exercised the surveillance camera pan, tilt, and zoom controls and the trailer turnon, turnoff, and alarm functions to the extent that their facilities permitted. The Caltrans District 12 TMC received video imagery and data from the three pairs of trailers performing ramp metering and video from the other three surveillance trailers. District 12 had the ability to remotely control VIP calibration and camera selection and positioning. The Anaheim TMC received video, but not data, from all the trailers and had control of camera selection and positioning. The UCI-ITS Laboratory received video imagery from the trailers, but could not select or control the cameras.

Objective 3 was qualitative. It identified the advantages, disadvantages, and costs associated with selecting the evaluation sites, transporting the trailers to them, and using the data for traffic management. Comments were solicited from Caltrans personnel involved with site selection, scheduling, performing the evaluation; TMC operations; and maintenance personnel who transported the trailers.

Objective 4, also qualitative, examined the institutional issues associated with sharing freeway video and data information among Caltrans, Anaheim, and the ITS Laboratory at UCI. Comments were solicited from Caltrans, Anaheim, and UCI personnel involved with scheduling and performing the evaluation and Caltrans and Anaheim TMC operations personnel.

After the I-5 Test began, Caltrans and the evaluator decided it would be beneficial to place one surveillance trailer in an actual construction zone to uncover the problems associated with such a deployment. Two sites were used in this portion of the study. The first location at Katella Avenue and I-5 was short lived as the contractor discovered that the trailer would interfere with his contractual road improvement responsibilities. After several weeks, an alternative site was found at the Katella Way onramp to the southbound I-5 near Manchester Avenue.

4.2 I-5 Test Locations

The maps in Figures 4-1 through 4-3 show the locations of the six surveillance trailers at Main Place, Grand Avenue, First Street, Tustin Ranch Road, Jamboree Road, and Culver Drive evaluation sites in north to south order along I-5. All, but the First Street trailer, were on the northbound side of the freeway. The relay site that retransmitted video and data from the surveillance trailers to the TMCs at Caltrans District 12 and Anaheim and to the ITS Laboratory at UCI is also indicated in Figure 4-2. During the evaluation, the trailers were powered from liquid propane fueled generators and storage batteries. The only exception was the surveillance trailer at Culver Drive that was connected to public utility landline power. With generator power, the unique aspects of trailer portability and reliability could be evaluated. On the other hand, the public utility power supplied to at least one trailer also allowed the alternate power system to be evaluated. Portable ramp meter trailers, including signal heads and meter-on signs, were placed at Grand Avenue, Tustin Ranch Road, and Jamboree Road. These locations were selected because they had ample room for the portable signal heads, ramp meter trailers, and meter-on signs. Photographs of the trailers and other equipment at the evaluation sites are shown in Figures 4-4 to 4-10.

The meter-on sign at Jamboree Road in Figure 4-9 is covered because it was not operational at the time this photograph was taken. The portable signal heads were placed in front of the permanent ones, which were covered to prevent confusion. Figures 4-11 to 4-16 contain layouts of the surveillance and ramp meter trailer placement at the six locations. Grand Avenue was the only site to use two ramp meter signal heads.

Table 4-2 lists the trailer identification numbers, number of ramp lanes metered, number of ramp meter signals deployed, and number of meter-on signs used at each site. All the surveillance trailers were used in support of the portability, image quality, and camera control portions of the quantitative evaluation. The trailers at the three ramp-metering locations were used to support the comparison of the ILD and VIP mainline and onramp data.

Table 4-2. Trailer and site deployment information

Site	Surveillance Trailer Number	Ramp Meter Trailer Number	Number of Ramp Lanes	Ramp Meter Signal Heads Deployed	Meter-on Sign Deployed
Main Place	115	n/a	n/a	n/a	n/a
Grand Avenue	109	17368	2	2	1
First Street	113	n/a	n/a	n/a	n/a
Tustin Ranch Road	114	17369	2	1	0
Jamboree Road	110	19280	2	1	1
Culver Drive	111	n/a	n/a	n/a	n/a

n/a = not applicable

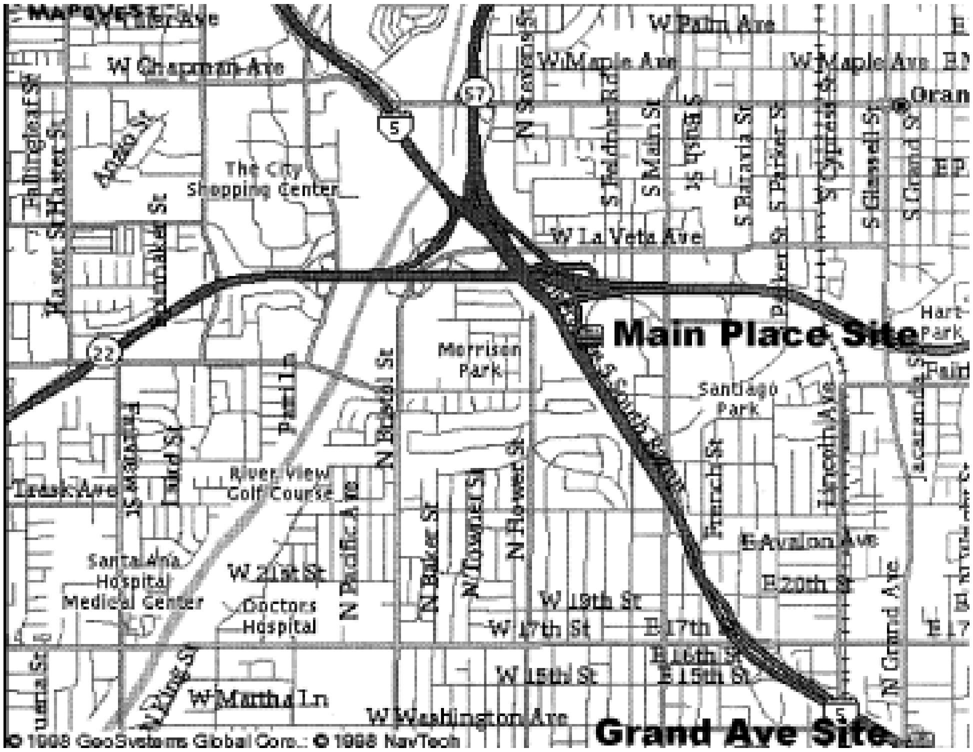


Figure 4-1. Main Place and Grand Avenue evaluation site locations along I-5

Figure 4-2. Grand Avenue and First Street evaluation site locations along I-5 and relay site on North Main Street between 10th and 11th Streets

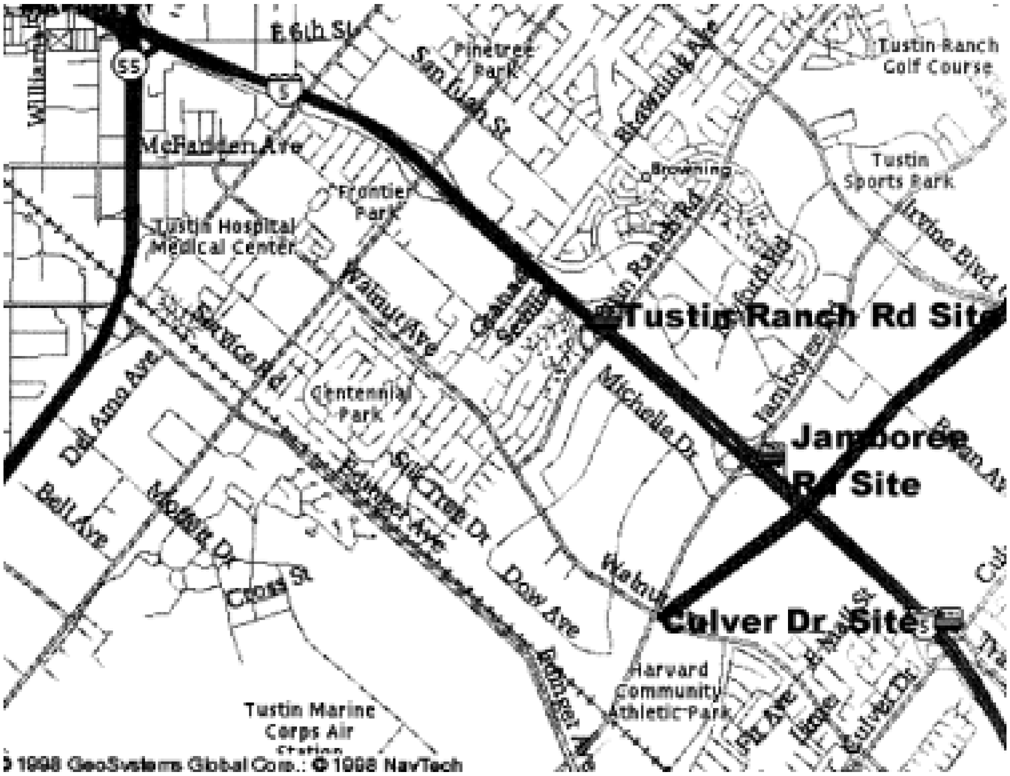


Figure 4-3. Tustin Ranch Road, Jamboree Road, and Culver Drive evaluation site locations along I-5

Figure 4-4. Surveillance trailer at Main Place looking south along I-5

(a) Surveillance trailer

(b) Ramp meter trailer

(c) Ramp signals

Figure 4-5. Surveillance and ramp meter trailers and signals at Grand Avenue

Figure 4-6. Surveillance trailer at First Street

Figure 4-7. Surveillance and ramp meter trailers at Tustin Ranch Road

(a) Onramp with surveillance trailer on left, ramp meter trailer and signal on right

(b) Surveillance trailer alongside of I-5 freeway

(c) Ramp meter trailer and signal

Figure 4-8. Surveillance and ramp meter trailers at Jamboree Road

Figure 4-9. Meter-on sign with solar panel at Jamboree Road ramp entrance

(a) Trailer and tow truck

(b) Trailer in position with mast extended

Figure 4-10. Surveillance trailer at Culver Drive

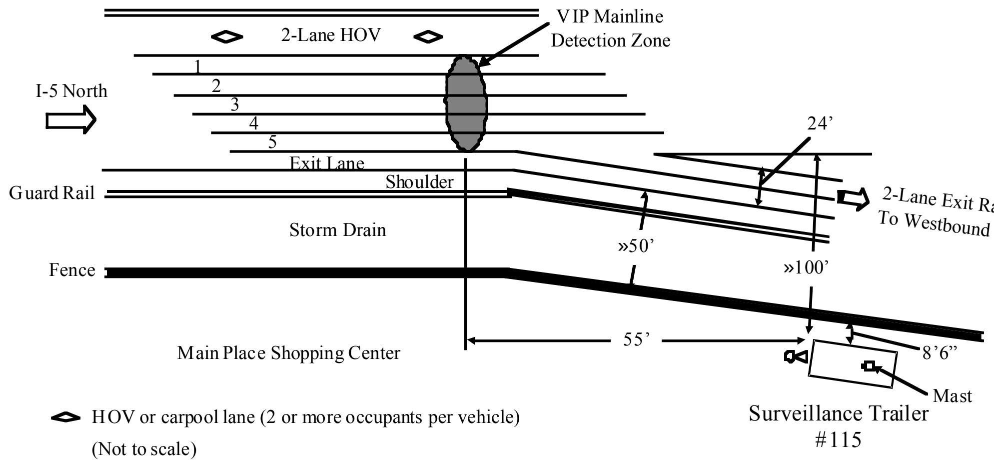


Figure 4-11. Trailer configuration at Main Place evaluation site

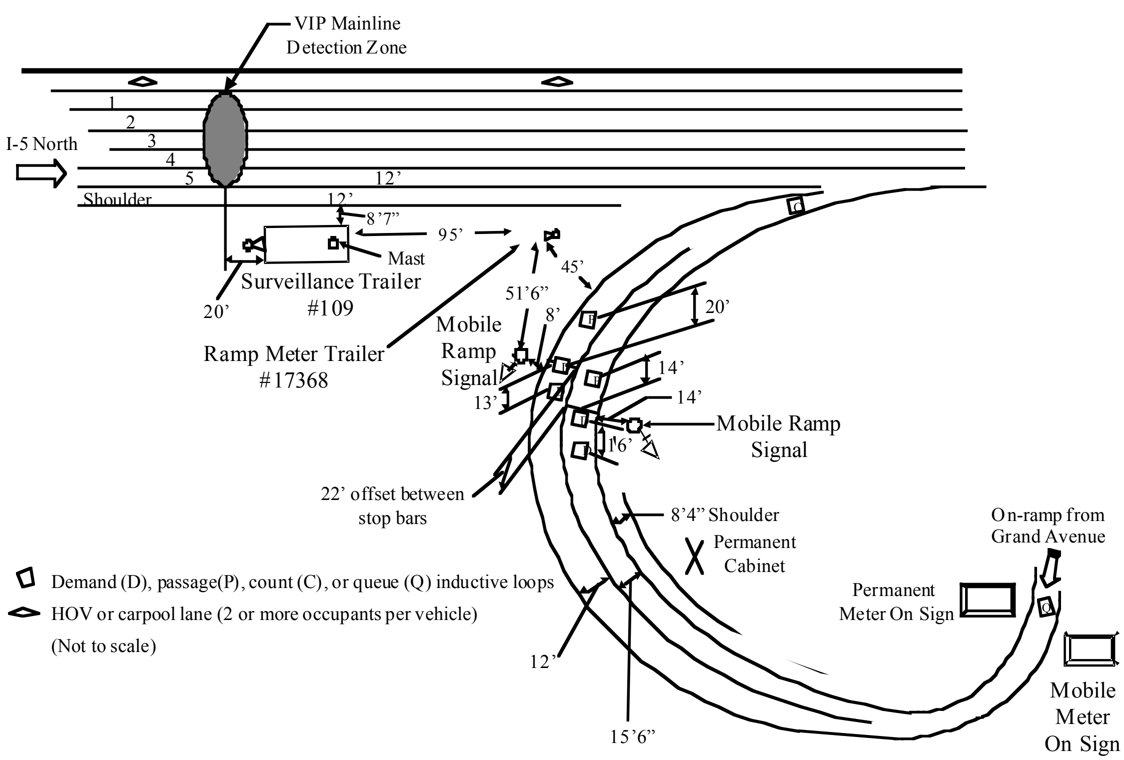


Figure 4-12. Trailer and ramp meter equipment configuration at Grand Avenue evaluation site

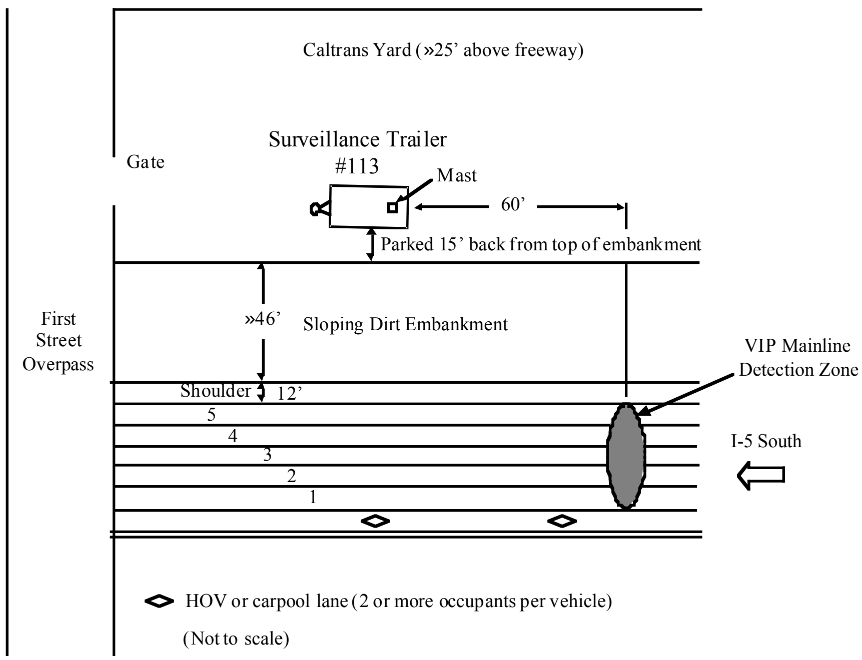


Figure 4-13. Trailer configuration at First Street evaluation site

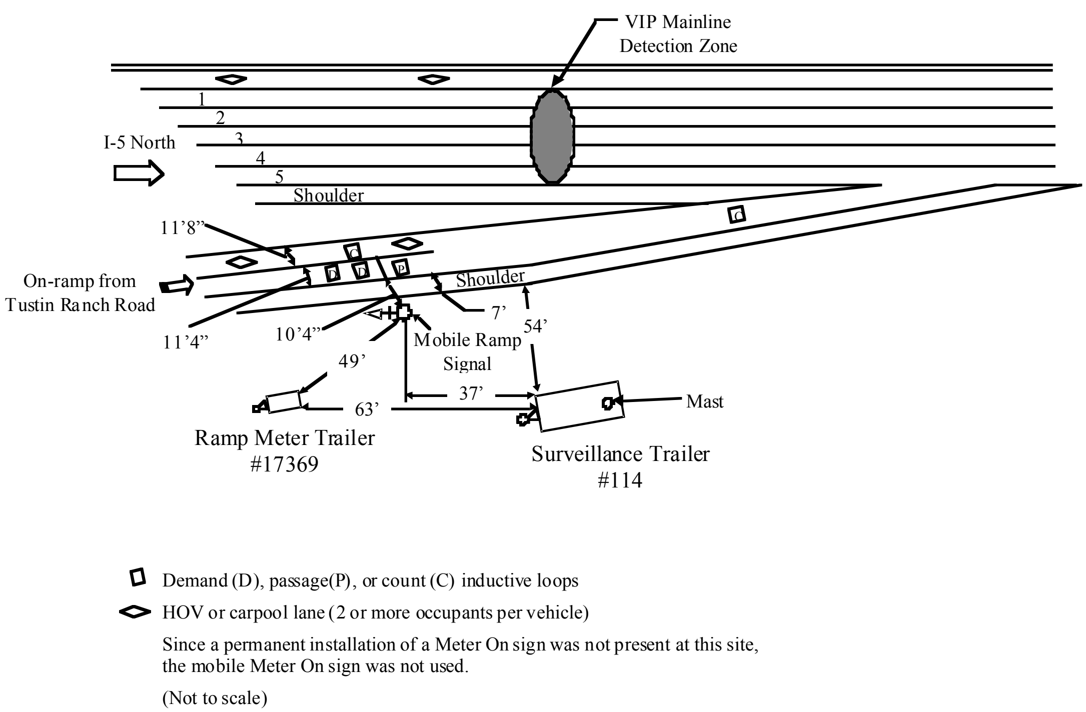


Figure 4-14. Trailer and ramp meter equipment configuration at Tustin Ranch Road evaluation site

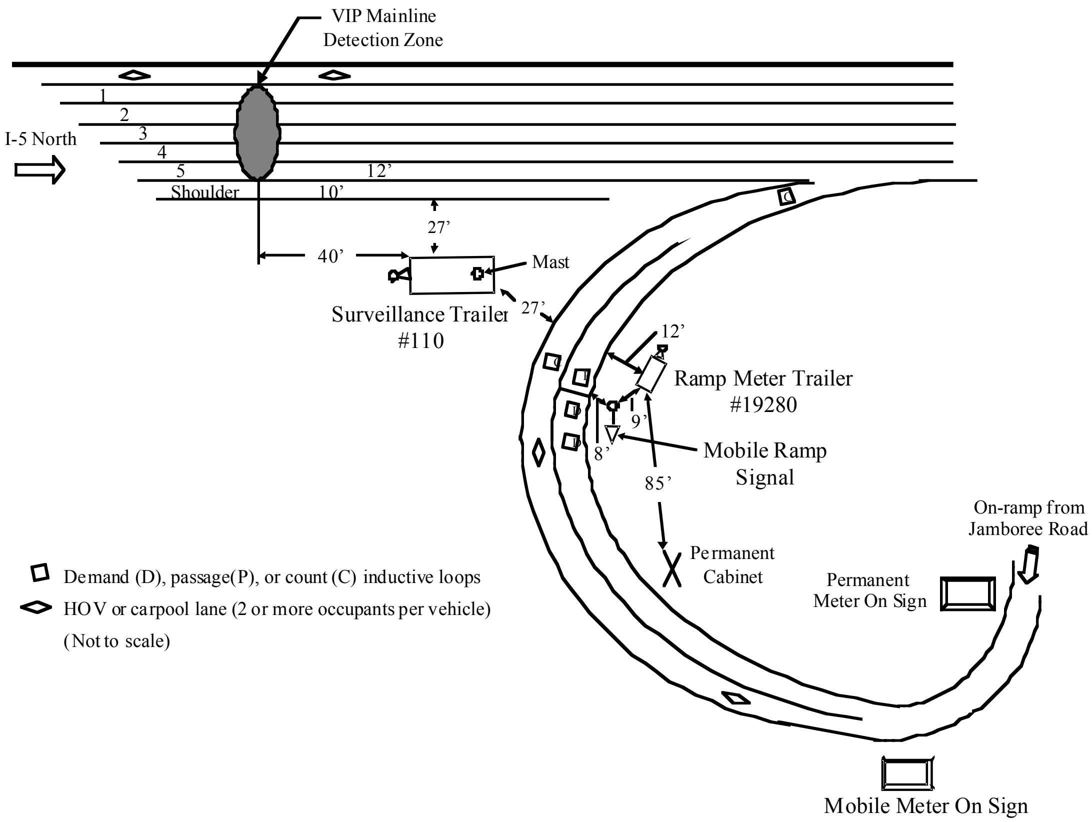


Figure 4-15. Trailer and ramp meter equipment configuration at Jamboree Road evaluation site

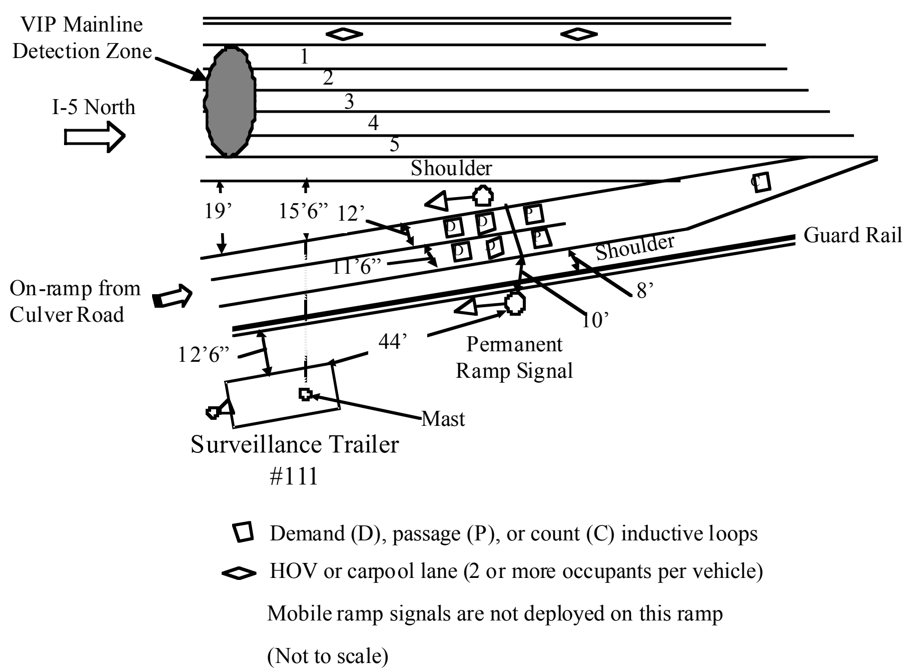


Figure 4-16. Trailer configuration at Culver Drive evaluation site

The distance of the surveillance trailer, and hence VIP camera, from the near edge of the right-most mainline lane (Lane 5) and from the near edge of the ramp (for the Grand Avenue, Tustin Ranch Road, and Jamboree Road trailers only) are listed in Table 4-3. These data may be useful in interpreting the differences obtained in the ILD- and VIP-measured traffic parameters.

Table 4-3. Distance of surveillance trailers from freeway mainline and onramps

Site	Surveillance Trailer Number	Distance of Surveillance Trailer From Mainline[4]	Distance of Surveillance Trailer From Ramp[5]
Main Place	115	≈114 feet (34.7 meters)	Not applicable
First Street	113	≈73 feet (22.3 meters)	Not applicable
Grand Avenue	109	20.6 feet (6.3 meters)	≈140 feet (42.7 meters)
Tustin Ranch Road	114	≈102 feet (31.1 meters)	65 feet (19.8 meters)
Jamboree Road	110	37 feet (11.3 meters)	27 feet (8.2 meters)
Culver Drive	111	71.5 feet (21.8 meters)	Not applicable

4.3 AutoScope Detection Zones

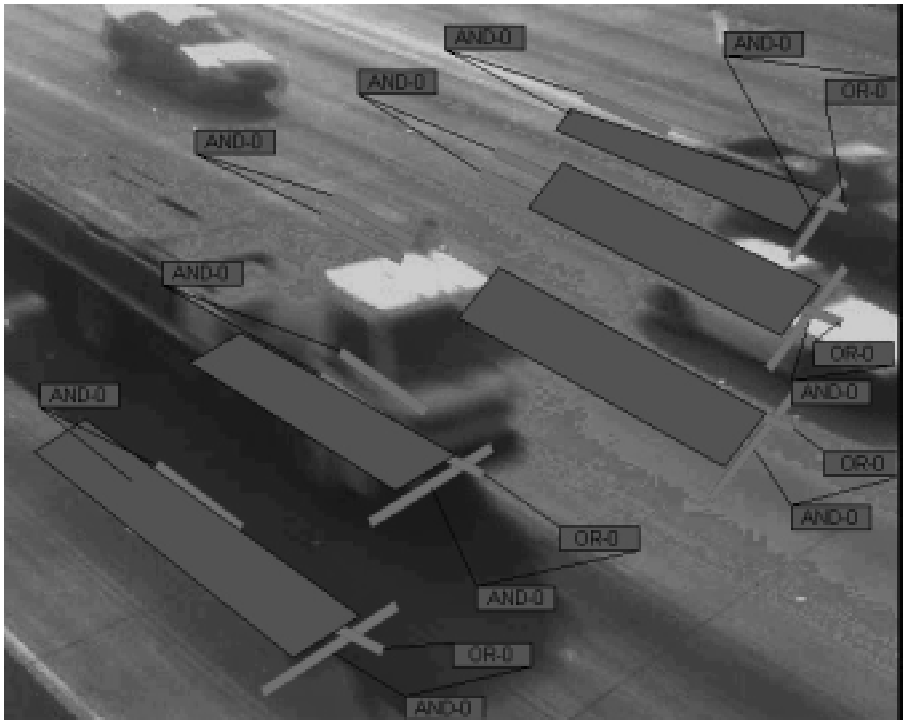
Figures 4-17 through 4-19 show the AutoScope 2004 VIP detection zones on the mainline and onramp at the three ramp meter evaluation sites. These images were downloaded from the supervisory computer used to configure the detection zones. On the mainline, count detectors were connected by AND logic to reduce false counts caused by image projection from vehicles into more than one lane. This was a noticeable problem brought on by the relatively low camera height and side-viewing geometry. Econolite placed speed (the long rectangular detection zone), presence, and demand detectors in the Grand Avenue mainline field of view to demonstrate the different options available for vehicle detection. The detectors used at Grand Avenue during the FOT are those on the left and upper portion of the image connected by AND logic. The detection zones on the ramp consisted of demand detectors. These detectors were connected by OR logic to increase the probability of vehicle detection by the VIP and the consequent change of signal from red to green. In addition to detectors parallel to traffic flow, detectors were configured in the shape of an X on the ramps to increase the probability that a vehicle was detected.

4.4 Impact of Equipment Failures on Test Schedule

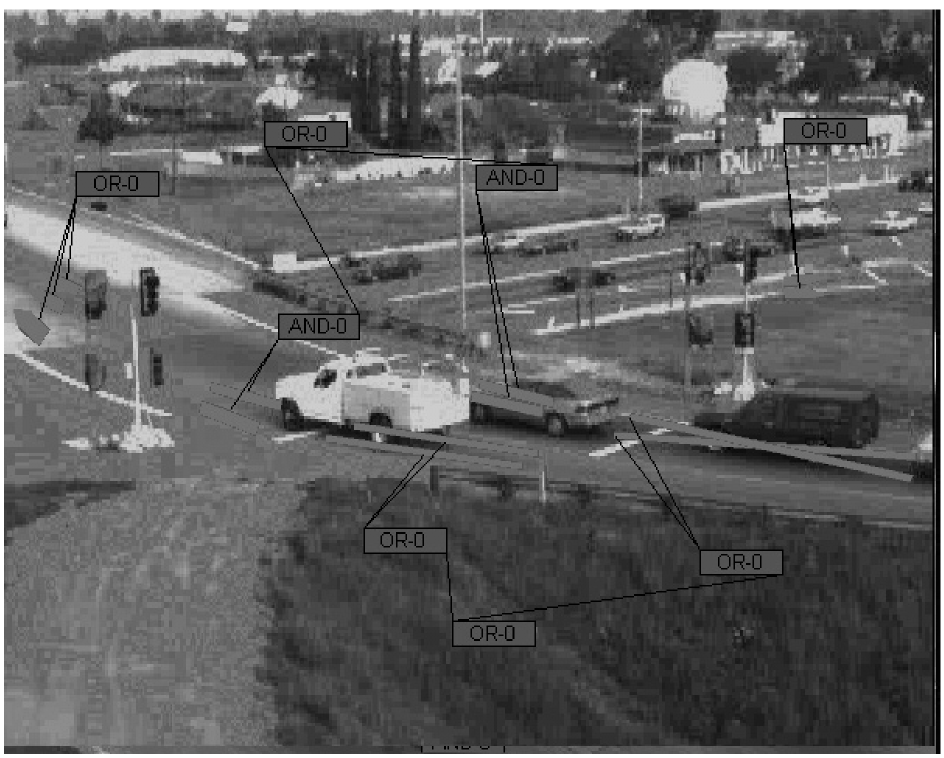
The I-5 Test was scheduled to begin Tuesday, June 17, 1997 following the completion of the System Acceptance Test (SAT). Since the SAT was postponed until November 1997, so was the start of the I-5 Test. The data to compare ILD- and VIP-measured traffic flow parameters were obtained between mid-January 1998 and May 1998.

4. The distance of the surveillance trailer, and hence VIP camera, from the near edge of the right-most mainline lane (Lane 5).

5. The distance of the surveillance trailer, and hence VIP camera, from the near edge of the ramp.

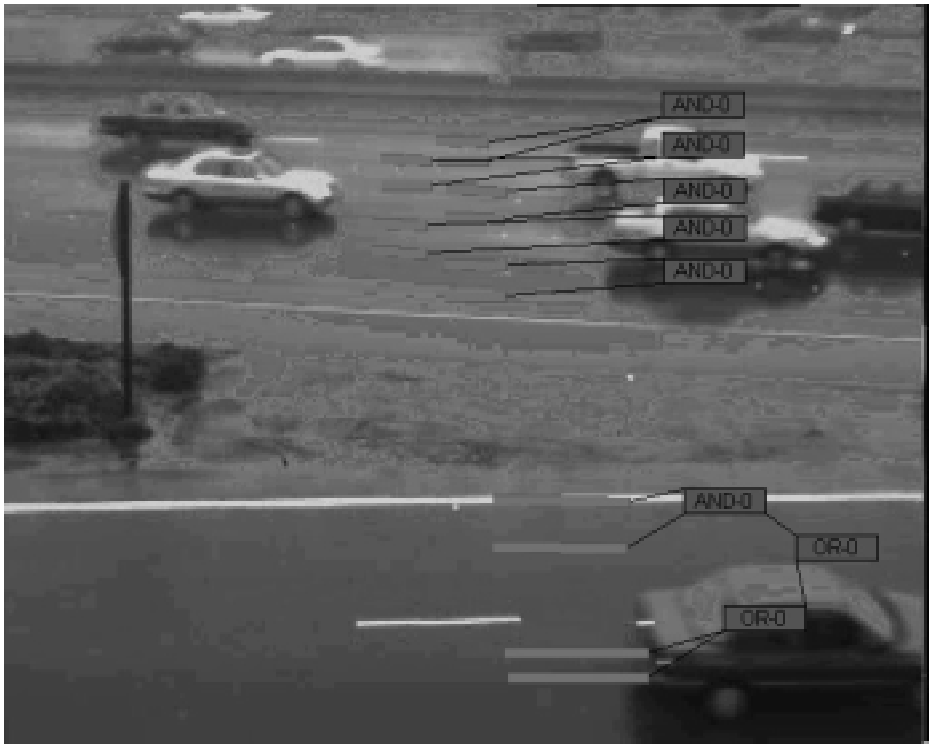


(a) Mainline detection zones

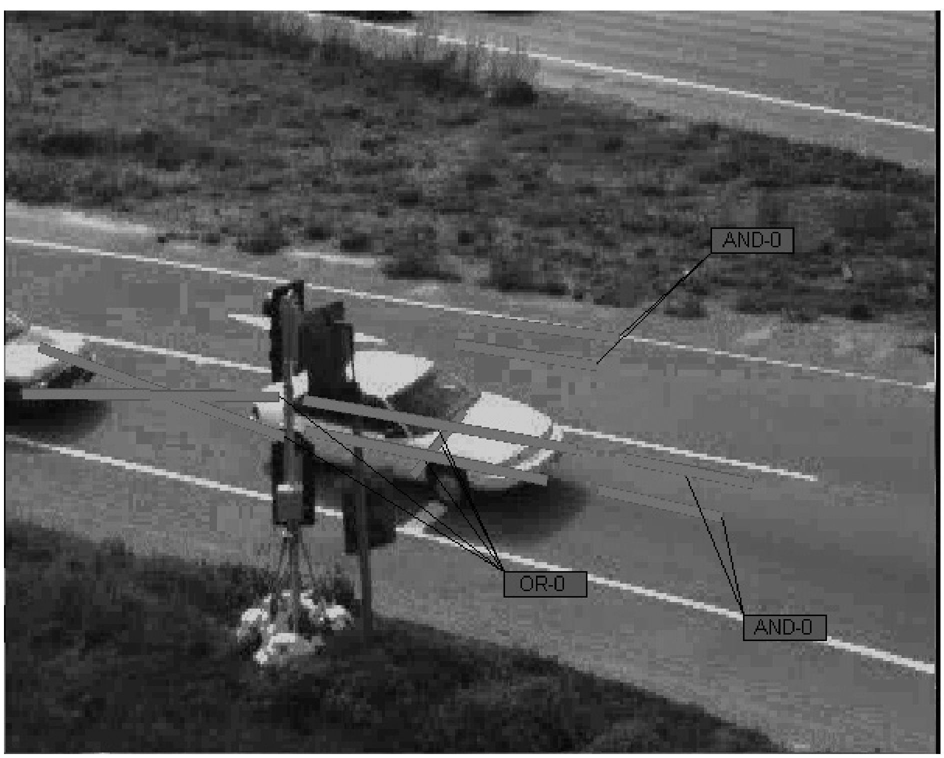


(b) Ramp detection zones

Figure 4-17. Mainline and ramp AutoScope detection zones at Grand Avenue



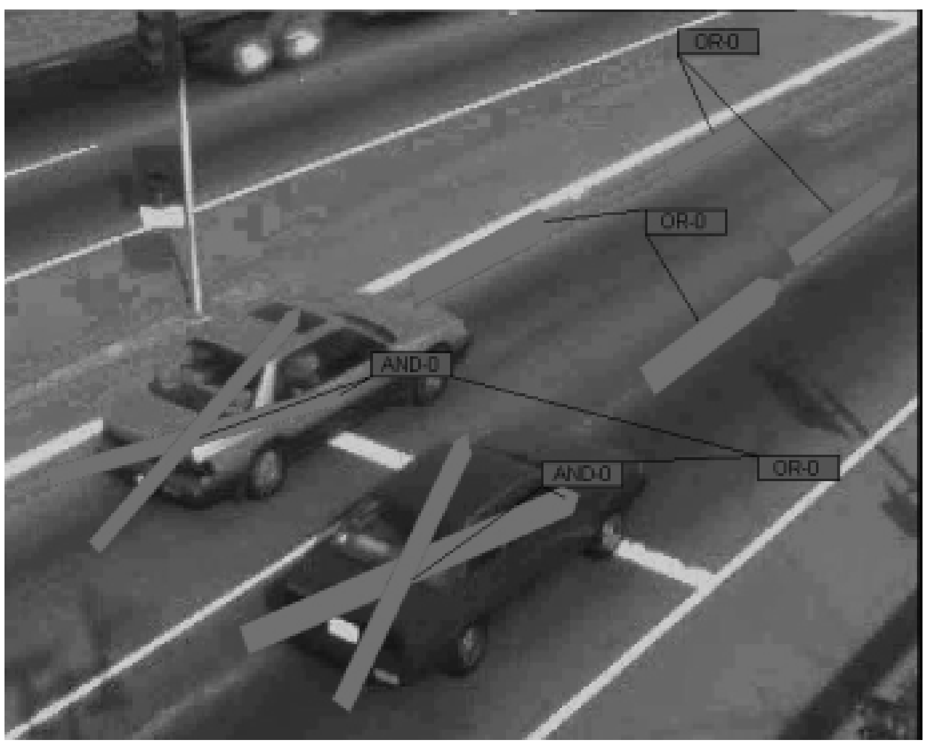
(a) Mainline detection zones



(b) Ramp detection zones

Figure 4-18. Mainline and ramp AutoScope detection zones at Tustin Ranch Road

(a) Mainline detection zones



(b) Ramp detection zones

Figure 4-19. Mainline and ramp AutoScope detection zones at Jamboree Road

Initially, several malfunctions and nonoptimal trailer operation were observed as summarized in Table 4-4. The most prevalent problem was frequent discharge of the surveillance trailer battery because the automatic generator start system that sensed the battery voltage was not functioning properly. Consequently, the generator had to be jump started from an automobile battery. At other times, the generator could not be started at all and service personnel had to be called. Eventually, the battery voltage sensing system was redesigned and the problem abated somewhat. The Culver Drive trailer had the fewest operating problems after it was connected to public utility power. The reliability of the Culver Drive trailer supported the conclusion that the generators and portable power system, in general, were the most troublesome part of the surveillance trailer system. After the FOT was completed, an extensive redesign of the generator, batteries, charging system, and power distribution architecture was completed. The new power system was installed in the six surveillance trailers, but was not evaluated as a part of the FOT.

Two other major design flaws affected the start of the ramp trailer evaluation. The first was loss of ramp meter signal synchrony with vehicle demand on the ramp and with the synchronizing signal from the surveillance trailer. The second was due to a misunderstanding between Caltrans and the system designers as to how the ramp meter signal sequence must operate when it first turns on. These flaws were corrected as indicated in Table 4-4 before the tests proceeded. The failures of isolators that control the power to ramp signal bulbs delayed the test, although they were replaced with relatively minor effort.

The nonoptimal trailer operation items included excessive generator on time resulting in frequent refueling of the surveillance trailers, failure to recharge batteries that resulted in the inability to start the trailer on succeeding days, generator failure due to a faulty generator component, and low fuel level causing delay of test. These and other minor annoyances are listed in Table 4-5.

Table 4-4. Malfunctions affecting start of evaluation test and their remedies

Site	Malfunction	Remedy
Main Place Surv.Trailer	Discharged battery	Jump start; install new battery and charging circuit
	Weak data reception at TMC	Realign antenna, check electrical connections
	Generator turning off and on for short intervals	Adjust load-bank on generator. Eventually had major redesign of battery charging circuit.
First Street Surv. Trailer	Discharged battery	Jump start; replace battery
Grand Avenue Surv. Trailer	Discharged battery	Jump start; adjust load-bank on generator
	Antenna moved by winds	Realign antenna
Grand Avenue Ramp Meter Trailer	Discharged battery	Jump start; reset battery charging threshold

Table 4-4. Malfunctions affecting start of evaluation test and their remedies (continued)

Site	Malfunction	Remedy
Grand Avenue and Jamboree Road	No communications to meter-on sign	Replace AM radio transmitter and receiver with improved FM models – major effort because of trailer wiring problems
Tustin Ranch Road Surv. Trailer	Starter failed	Replace starter
Jamboree Road Surv. Trailer	Generator auto start/stop system not operating properly	Redesign auto stop/start system and software – a major effort
	Frequently found battery dead and could not start trailer	Redesign power generation and distribution system after completion of FOT – a major effort
Culver Drive Surv. Trailer	Frequently found battery dead and could not start trailer (before connecting to commercial power)	Redesign power generation and distribution system after completion of FOT – a major effort
All ramp meter trailers	Ramp meter red/green signal lost synch with ramp demand and surveillance trailer commands	Reduce data transmission rate from surveillance trailer radio transmitter to ramp meter trailer radio receiver
	Yellow signal not programmed to turn on at beginning of metering interval	Modify software so that ramp signal went from green, to extended yellow, to red at beginning of metering interval - a major effort
Tustin Ranch Road Ramp Meter Trailer	Isolator that sends power to signal bulb failed	Replace isolator
Jamboree Road Ramp Meter Trailer	Isolator that sends power to signal bulb failed	Replace isolator

Table 4-5. Annoyances with trailer performance during the I-5 Test

Site	Malfunction	Remedy
Tustin Ranch Road Surv. Trailer	Frequently oil level low, ants in trailer	Add oil, spray trailer for ants, and set ant traps
Culver Drive Surv. Trailer	Winds of 40 to 50 mph (64 to 80 km/hr) misaligned antenna	Reposition antenna for maximum signal to relay site
Culver Drive Surv. Trailer	DC to AC inverter failed	Replace inverter and blown fuse in 170 controller
All trailers	Generators either ran more frequently than desired or did not keep batteries charged	Redesign auto stop/start circuit for the generator - a major effort

4.5 Trailer Deployment and Data Collection Procedures

The process of deploying the surveillance and ramp meter trailers and collecting the evaluation data consisted of four steps, namely trailer transport, trailer setup, surveillance trailer operation, and ramp meter trailer operation. Prior experience with trailer deployment was gained during the Anaheim Special Event Test in March, April, and May 1997. A dry run of most of the I-5 Test evaluation activities occurred during the SAT on November 14, 15, and 17 1997.

Step 1. Trailer Transport

During the Anaheim Special Event Test in April 1997, surveillance trailers were moved to the three surveillance-trailer-only sites in preparation for the Systems Acceptance Test originally scheduled for June 26, 1997. Therefore, Caltrans District 12 Maintenance only needed to transport a surveillance trailer and a ramp meter trailer to the three ramp meter evaluation sites as part of the trailer transport process for the I-5 Test. The first three locations below were the sites where surveillance trailers were already in place. The last three are the sites where trailers were transported at the start of the test.

- Surveillance Trailer #115,
  Already located, Northbound I-5 at Main Place Shopping Center.
- Surveillance Trailer #113,
  Already located, Southbound I-5 at First Street.
- Surveillance Trailer #111,
  Already located, Northbound I-5 at Culver Drive.
- Moved Surveillance Trailer #110 and Ramp Meter Trailer #19280
  to Northbound I-5 at Jamboree Road.
- Moved Surveillance Trailer #114 and Ramp Meter Trailer #17369
  to Northbound I-5 at Tustin Ranch Road.
- Moved Surveillance Trailer #109 and Ramp Meter Trailer #17368
  to Northbound I-5 at Grand Avenue.

Once the trailers were deployed, they were not moved until the I-5 Test was completed in May 1988. The evaluation plan, though, did allow one of the trailers not at the ramp sites (Trailer #111, #113 or #115) to be relocated to support other research or operational activities after the initial four week evaluation period was complete.

Step 2. Trailer Setup

The trailers were set in place and checked for proper operation upon reaching the evaluation site. Caltrans was responsible for this activity with assistance from Hughes. Econolite also assisted in VIP detection zone setup and calibration.

During trailer transport and setup, data were collected to support Test Objective 1 (Examine Portability). The evaluators measured the time to complete the transport and setup tasks as recorded on data sheets shown in Appendix E. The data collection procedure is described in Section 4.6.1.4.

Step 3. Surveillance Trailer Operation

The surveillance trailers were operated at designated times to verify camera image quality and control and traffic detection via video image processing. Video image quality and camera control were monitored at the Caltrans District 12 and Anaheim TMCs. VIP data verification was planned for the District 12 TMC, the only location that could receive data. Video image quality checks were also conducted at the UCI-ITS Laboratory. Personnel were designated at each location to be responsible for gathering the required information and data. They were permitted to delegate their responsibility to another staff member after notifying the evaluators of the proposed change.

Figure 4-20 shows a District 12 TMC workstation from which camera control, image quality checks, and data acquisition could occur.

Figure 4-20. Caltrans District 12 workstation displaying camera selection icons on the left monitor

Camera control and image quality were checked more frequently on the first day of the test, when "Hourly" checks occurred at the District 12 TMC beginning at 6:00 a.m. Each camera control function and image was monitored approximately every hour until about 3 p.m. At the Anaheim TMC, beginning at 9:00 a.m. on the first day, each camera image and each camera control were checked every two hours for the eight hour period ending at 5:00 p.m. For the UCI-ITS Laboratory, beginning at 12:00 noon on the first day, each camera image was to be checked every three hours for one six hour period (ending at 6:00 p.m.). The schedule was designed to simultaneously share equipment use among two and three locations and uncover any problems that might arise. In fact, it soon became apparent that there was a conflict in the simultaneous reception of video imagery at Anaheim and UCI. Whenever one of these sites had the SSR video receiver on, the other could not receive imagery. Since it was inconvenient to turn the receiver at UCI on and off several times a day (as it was located on a roof with controlled access), it was left off for most of the test. Towards the end of the testing period, a remote switch was installed at UCI so that the video SSR receiver could be turned off from the fifth floor ITS transportation laboratory. Video image reception was verified at UCI on two occasions, one during the SAT and one towards the end of the I-5 Test after the switch was installed and Anaheim had been instructed to turn their receiver off.

The frequency of camera control and image quality data collection at the District 12 TMC was reduced to three times a day on the second through fourteenth days of testing. Data on these days were acquired in early morning, noon, and in the afternoon. Three days of once to twice-a-day testing followed, with data acquisition in the early morning or early morning and afternoon. Anaheim followed a similar schedule.

The Automated Traffic Management System at District 12 was checked for VIP and ILD data four times in the morning and three times during the afternoon of the first day of testing. Over the next five days of testing, the ATMS was interrogated one to four times a day in an attempt to retrieve VIP and ILD data. At best, the ILD data were updated in an inconsistent manner and the VIP data did not appear at all. Discussions were held with the contractor who developed the ATMS software and with Hughes concerning these problems. Attempts were made to remedy the problems, but the data remained unavailable from the ATMS for the duration of the FOT.

Since the start of data acquisition for the I-5 Test was delayed by almost a year (Spring 1997 to Spring 1998), there was not enough time to gather data on a weekly and monthly schedule. Problems with synchronizing commands from the surveillance trailer to the ramp meter trailer, a software modification to incorporate a long yellow signal in the ramp meter turnon sequence, frequent power system failures in the trailers, and the inability of the District 12 ATMS to poll the 170 controllers attached to the VIPs subjected the data acquisition schedule to additional delays. As a result, only about two and a half days of quantitative data, comparing ILD- and VIP-measured traffic volumes and lane occupancies, were obtained at each of the ramp meter sites during Spring 1998. Data concerning camera control and image quality were obtained over a longer time interval as these activities could proceed in the presence of some of the above problems.

The cameras in each trailer were checked in sequence starting with Camera #1 (mainline VIP) image and data, Camera #2 (onramp VIP) image and data, Camera #3 (surveillance only) image and camera pan, tilt, zoom control, and Camera #4 (security). The results were recorded on the Camera Operability and VIP Believability Data Sheets provided by the evaluator (as shown in Appendices D and E). The evaluator coordinated and assisted with the data collection activity. The same data sheets were used to note any problems uncovered during the test. The associated data collection procedure is described in Section 4.2.2.4. As the mainline and ramp data produced by the VIPs were not being displayed on the District 12 ATMS, the VIP Believability data collection was discontinued after the sixth day.

Independent of the scheduled checks, the surveillance trailers at each evaluation site could be turned on as needed for location-specific traffic monitoring or research activities. Each time a surveillance trailer was used for real-time traffic management or as part of a technology demonstration, the responsible party was to record the date, time, event type, problems encountered, and any coordination required between the District 12 TMC, Anaheim TMC, and UCI-ITS Laboratory.

Step 4. Ramp Meter Trailer Operation

The surveillance and ramp meter trailers at each ramp meter site were turned on and off at the beginning and end of the ramp-metering periods to conserve fuel. When metering, the ramp meter trailers transmitted the metering rates received from the surveillance trailers to the ramp signals that regulated traffic from the onramp onto the mainline of the freeway. The ramp-metering period was scheduled in the morning from 06:00 hours until 09:30 hours. In the afternoon, the metering period was from 15:00 hours until 19:00 hours. The original ramp meter rates were the same as those in the time-of-day table stored in the 170 controller at the evaluation site.

The primary ramp meter functionality checks and data acquisition were performed at the ramp meter locations. Ramp meter data were also supposed to be available at the District 12 TMC. However, with the failure of the ATMS to display the 170 controller data captured from the VIPs and its inconsistent updating of the ILD data, we relied exclusively on data collected at the evaluation sites. Caltrans was responsible for performing the primary ramp meter checks with assistance of the evaluator. TMC personnel were responsible for the camera control and image quality checks.

Ramp meter functionality was checked more frequently early in the test. When the test began, the evaluators remained at the sites for several hours to ensure that the ramp signals were changing in synchronization with vehicle demand and surveillance trailer commands. Once the equipment was functioning without problems, the original evaluation plan specified that data acquisition begin at 06:00 hours on the first day, with “Hourly” checks of ramp meter functionality. Data acquisition continued for the duration of the a.m. traffic period (ending at 09:30 hours). During the afternoon peak period, beginning at 15:00 hours, each ramp meter site was checked every hour for the duration of the p.m. peak period (ending at 19:00 hours). In fact, what occurred in the field was the continuous recording of ILD and VIP data on laptop computers for the duration of the morning and afternoon rush hour periods. The synchronization of vehicle demand and signal response was also verified hourly.

The frequency at which the mobile ramp metering was checked was to be reduced from hourly to daily to weekly to monthly. Because of the delays in starting the test, only the hourly schedule was utilized.

Because the ATMS could not display the 170 controller data captured form the VIPs, each ramp site was evaluated separately, rather than concurrently. This procedure was used because two laptop computers were needed at each site to record data and only two computers were available. In the field, Caltrans and the evaluator checked that all equipment, including the ramp meter-on sign, was in the proper state and that vehicle presence and passage were properly detected. Vehicle presence detection was verified by noting if the ramp signal alternated between green and red when vehicles were present, and if the signal remained red when vehicles were not present. Ramp queue overflow detection was checked by recording the times when the ramp queue extended beyond the start of the onramp. This event was only detectable by the ILDs since the VIP camera was aimed at the end of the ramp, near the signal, and not the start of the ramp where queue overflow would occur.

Caltrans recorded the results of these checks on the Ramp Meter Operability Data Sheets provided by the evaluator (see Appendix H). The same data sheets were used to note any problems uncovered during the test. More detailed descriptions of the associated data collection procedures are given in Section 4.6.2.9.

4.6 Evaluation Results

Several of the tasks in the I-5 Test Evaluation Plan could not be performed because the data needed were not available. These instances are noted. Some test evaluation data dealing the trailer portability were collected in April and June 1997 when trailers were set in place for the SAT. These trailer transport data sheets are included in Appendix E.

4.6.1 Test Objective 1 - Portability

The objective of the portability evaluation was to assess the ease with which the surveillance and ramp meter trailers were moved into the field, setup, and made operational in support of the I-5 Test.

4.6.1.1 Measures of Performance

The measures of performance for this assessment are:

- Measure 1.1: Pre-transport preparations
- Measure 1.2: Time to hitch, transport, setup, make operational
- Measure 1.3: Transport and setup obstacles, problems, and remedies.

4.6.1.2 Test Data

The data collected in support of each performance measure are:

Measure 1.1: Pre-transport preparations

Data 1.1.1: Identity of pre-transport preparations

Data 1.1.2: Level-of-effort for pre-transport preparations

Measure 1.2: Time to hitch, transport, setup, and make operational

Data 1.2.1: Number of minutes to hitch surveillance trailer

Data 1.2.2: Number of minutes to transport surveillance trailer

Data 1.2.3: Number of minutes to setup surveillance trailer

Data 1.2.4: Number of minutes to hitch ramp meter trailer

Data 1.2.5: Number of minutes to transport ramp meter trailer

Data 1.2.6: Number of minutes to setup ramp meter trailer

Data 1.2.7: Number of minutes to make trailer set operational

Measure 1.3: Transport and setup obstacles, problems, and remedies

Data 1.3.1: Identity of transport and setup obstacles, problems, and remedies

Data 1.3.2: Severity of transport obstacles, problems, and remedies

4.6.1.3 Data Collection Procedures for Performance Measure 1.1

The procedures for collecting the data in support of Objective 1 are described below.

Data 1.1.1: Identity of pre-transport preparations

Panning for the trailer deployment planning occurred over many months, resulting in a list of pre-transport preparation topics. The topics are:

Preparation 1: Site Selection

Preparation 2: Site Survey

Preparation 3: Site Readiness

Preparation 4: Trailer Readiness

The evaluator requested written statements from Caltrans confirming that this list was complete in that it correctly identified each pre-transport preparation topic. The result of this activity was Data 1.1.1, the identity of pre-transport preparation items.

Data 1.1.2: Level-of-effort for pre-transport preparations

The pre-transport preparations for the I-5 Test were similar to those encountered for the Anaheim Special Event Test as reported earlier. There was not any new information in the form of statements from the PMT members that addressed specific I–5 Test pre-transport preparations. Rather, problems and their solutions were noted by annotating the Trailer Transport Data Sheets and surveillance trailer and ramp meter trailer logs. The information that addresses the impact of trailer readiness on the test schedule has been presented in Tables 4-4 and 4-5 of Section 4.3.

4.6.1.4 Data Collection Procedures for Performance Measure 1.2

The methods for collecting the data associated with Performance Measure 1.2 (time to hitch, transport, set in place, and make operational) are identical. Thus, these data items are covered concurrently in this section.

- **Data 1.2.1: Number of minutes to hitch surveillance trailer**
- **Data 1.2.2: Number of minutes to transport surveillance trailer**
- **Data 1.2.3: Number of minutes to set in place surveillance trailer**
- **Data 1.2.4: Number of minutes to hitch ramp meter trailer**
- **Data 1.2.5: Number of minutes to transport ramp meter trailer**
- **Data 1.2.6: Number of minutes to set in place ramp meter trailer**
- **Data 1.2.7: Number of minutes to make trailer pair operational**

The evaluator observed each trailer transport event and coordinated the collection of test data. The evaluator was contacted by Caltrans to confirm the departure point and start time no less than 24 hours prior to each scheduled trailer transport event. The departure point was the current location of the trailer to be transported. The start time was the time the transport crew arrived at the departure point.

The evaluator arrived at the departure point at least 10 minutes prior to the start time with a watch and a Trailer Transport Data Sheet that contained six columns including one for comments. Appendix E contains the Trailer Transport Data Sheets used to record the time of the transportation milestones. The milestones were "Began", " Hitched", " Arrived", "Set in Place", and “Departed”. Separate sheets were used for the surveillance and ramp meter trailers. When the Caltrans transportation crew was ready to begin towing operations (i.e., raising outriggers, lowering mast, reorienting cameras and antenna, making trailer mechanical and electrical connections, etc.), that time was recorded in the "Began" field. When the trailer was hitched and ready to transport, that time was recorded in the " Hitched" field. When the trailer arrived at the destination site, that time was recorded in the "Arrived" column. When the trailer was set in place (i.e., in its final location with the trailer level, outriggers extended, and wheels chocked) so that checkout could proceed, that time was recorded in the "Set" field. The time when the tow truck and crew departed the test site (with the trailer operational) was written in the “Departed” field. When two trailers were moved at the same time, two tow trucks and two crews were used, and the corresponding times for each trailer were entered on datasheets designated for each of the surveillance and ramp meter trailers. Throughout the transport and setup process, any observed problems and obstacles were noted in Column 6 reserved for comments.

Data 1.2.1, the number of minutes to hitch a surveillance trailer, was computed as the difference between the "Began" time and the "Hitched" time.

Data 1.2.2, the number of minutes to transport a surveillance trailer, was computed as the difference between the "Hitched" time and the "Arrived" time.

Data 1.2.3, the number of minutes to set a surveillance trailer in place, was computed as the difference between the "Arrived" time and the "Set" time.

Data 1.2.4, the number of minutes to hitch a ramp meter trailer, was computed as the difference between the "Set" time and the "Hitched" time.

Data 1.2.5, the number of minutes to transport a ramp meter trailer, was computed as the difference between the "Hitched" time and the "Arrived" time.

Data 1.2.6, the number of minutes to set a ramp meter trailer in place, was computed as the difference between the "Arrived" time and the "Set" time.

Data 1.2.7, the number of minutes to make the trailer combination operational, was computed for each surveillance trailer-ramp meter trailer set as the time difference between the "Ramp Meter Set" time and the "Depart" time, or the “Surveillance Trailer Set” time and the "Depart" time, whichever gave the larger interval.

The evaluator recorded the data; calculated the hitch, transport, set in place, and make operational times; and summarized the results as shown in Tables 4-6 and 4-7. The hitch times were less than 10 minutes when the trailers were functioning properly and all of the parts required for the operation were at hand. As found in the Anaheim Special Event Test, the transport times were a function of the distance traveled to the evaluation site. The set in place times were larger when the ramp meter trailers were part of the deployment. Time was needed to unload the signal heads and meter-on sign from the trailer and erect them at the desired locations. Usually a boom truck and a crew of at least five were required to unload and assemble the signal heads.

Table 4-6. Trailer hitch, arrived, set, and departed data

Destin -ation	Move Date	Trailer Number	Began	Hitched	Arrived	Set	Departed	Comments
I-5 at Culver Drive	4/10/97	111 (Surv.)	8:09am	8:24am 8:55am	8:45am 9:12am	9:17am	9:27am*	Add air to tires at Caltrans yard; another

								commitment prevented completion of checkout
I-5 at First Street	4/10/97	113 (Surv.)	9:42am	9:50am	≈10:10am 10:27am	10:32am	10:49am	Add air to tires at Caltrans yard
I-5 at Main Place	4/10/97	115 (Surv.)	11:05am	11:14am	11:40am	11:45am	12:40pm	Color bar noise on video received at Anaheim TMC
I-5 at Jamb-oree Road	6/3/97	110 (Surv.)	9:27am	9:52am 10:15am	10:55am	11:13am	1:10pm	Delay leaving Hughes lot: trailer lights not working and washed trailers
I-5 at Jamb-oree Road	6/3/97	19280 (Ramp)	9:09am	9:15am 10:15am	11:17am	11:34am	1:10pm	Departed before ramp meter signal sequence was verified
I-5 at Grand Ave.	6/14/97	109 (Surv.)	5:48am	6:09am 7:18am	7:50am	8:55am	12:30pm	Delay leaving Hughes lot: Searched for D-clamps, pumped tires, and washed trailers

Table 4-6. Trailer hitch, arrived, set, and departed data (continued)

Destin-ation	Move Date	Trailer Number	Began	Hitched	Arrived	Set	Departed	Comments
I-5 at Grand Ave.	6/14/97	17368 (Ramp)	6:00am	6:15am 7:18am	7:50am	9:42am	---	Ramp meter signal sequence not verified; meter-on sign not working
I-5 at Tustin Ranch Road	6/18/97	114 (Surv.)	7:20am	7:35am 8:05am	9:00am	11:10am	2:40pm (Includes 1-hr lunch break)	Washed trailers before leaving lot; re-examined site for best trailer location
I-5 at Tustin Ranch Road	6/18/97	17369 (Ramp)	7:20am	7:35am 8:05am	9:00am	10:45am	11:00am	Washed trailers before leaving lot

* Checkout not completed for reasons stated in the table. Therefore, the time to make the trailer operational could not be calculated for this data set.

Table 4-7. Hitch, transport, set in place, and make operational times

Destination	Trailer Move Date	Trailer Number	Hitch Time (min)	Transport Time (min)	Set in Place Time (min)	Make Operational Time (min)
Culver Drive	4/10/97	111	15	21	—	—
Culver Drive	4/10/97	111	—	17	5	*
First Street	4/10/97	113	8	20	5	17
Main Place	4/10/97	115	9	26	5	55
Jamboree Rd.	6/3/97	110	25	40	18	117
Jamboree Rd.	6/3/97	19280	6	62	17	—
Grand Ave.	6/14/97	109	21	32	65	215
Grand Ave.	6/14/97	17368	15	32	112	—
Tustin Ranch Rd.	6/18/97	114	15	55	130	175
Tustin Ranch Rd.	6/18/97	17369	15	55	105	—
Mean			14	36	51	116
Std. Deviation			7	15	49	73

* Checkout not completed for reasons stated in Table 3-1.

The moderately large time for Trailer 115 at Main Place to become operational was due to the weak signal received at the Anaheim TMC. Extra time was required for moving the trailer to a potentially better location and realigning the trailer antenna to improve the signal strength. At this point in the evaluation, none of the ramp meter signals was reliable. Either they immediately failed to synchronize with vehicle demand or commands from the surveillance trailer, or they lost synchronization after several minutes. It was not until after the SAT that this problem was isolated and fixed by lowering the transmission rate of the commands from the surveillance trailer to the ramp meter trailer.

4.6.1.5 Data Collection Procedures for Performance Measure 1.3

This section contains the data collection procedures for Performance Measure 1.3, transport and setup obstacles, problems, and remedies.

Data 1.3.1: Identity of transport and setup obstacles, problems, and remedies

Trailer transport activities for the I-5 Test were completed June 18, 1997. Based on the transport activities, the evaluator compiled a list of transport and setup problems, obstacles, and remedies from entries on the Trailer Transport Data Sheets and the logs kept in each surveillance trailer. The result of this activity was Data 1.3.1, the identity of transport and setup obstacles, problems, and remedies. These data have already appeared in Tables 4-4 and 4-5 of Section 4.4.

Data 1.3.2: Severity of transport obstacles, problems, and remedies

When information about the severity of the transport obstacles, problems, and remedies was provided to the evaluator, it was incorporated into Data Item 1.3.1 as indicated in Tables 4-4 and 4-5.

4.6.2 Test Objective 2 - Effectiveness of Trailers for Traffic Management

The objective developed for determining the effectiveness of the trailers for traffic management had three parts. The first was to determine if the video imagery provided by the surveillance trailers was suitable for viewing freeway traffic. The second was to determine if the data provided by the surveillance trailers were suitable for assessing freeway traffic flow parameters. The third was to determine if the ramp meter trailers were suitable for metering traffic from freeway onramps onto freeway mainlines.

4.6.2.1 Measures of Performance

The measures of performance for this assessment are:

- Measure 2.1: Camera image and control availability
- Measure 2.2: Camera image and control problems
- Measure 2.3: VIP data availability
- Measure 2.4: VIP data believability
- Measure 2.5: Ramp meter on/off functionality
- Measure 2.6: Ramp meter vehicle presence treatment

- Measure 2.7: Ramp meter problems.

4.6.2.2 Test Data

The data collected in support of each performance measure are:

Measure 2.1: Camera image and control availability

Data 2.1.1: Camera image percent up time

Data 2.1.2: Camera control percent up time

Measure 2.2: Camera image and control problems

Data 2.2.1: Identity of camera image and control problems

Measure 2.3: VIP data availability

Data 2.3.1: VIP percent up time

Measure 2.4: VIP data believability

Data 2.4.1: Percent VIP data match video assessment

Measure 2.5: Ramp meter on/off functionality

Data 2.5.1: Percent ramp signal correctly powered on/off

Data 2.5.2: Percent meter-on sign correctly powered on/off

Measure 2.6: Ramp meter presence treatment

Data 2.6.1: Percent proper vehicle presence response

Measure 2.7: Ramp meter problems

Data 2.7.1: Identity of ramp meter problems

4.6.2.3 Data Collection Training

The evaluation staff was trained in the data collection procedures no sooner than one week before data collection began so that the procedures could be easily recalled. Training included visits to the trailers, TMCs, and UCI-ITS Laboratory, as needed.

4.6.2.4 Data Collection Procedures for Performance Measure 2.1

Data 2.1.1 and Data 2.1.2 were gathered concurrently and thus are described together.

Data 2.1.1: Camera image percent up time

Data 2.1.2: Camera control percent up time

Several evaluators were involved in the first stages of collecting data for this performance measure. The multiple evaluator phase lasted about one week. One evaluator observed camera image quality, camera control, and VIP data believability checks and coordinated the collection of test data at the District 12 TMC. A second evaluator performed similar functions at the Anaheim TMC, and a third at the UCI-ITS Laboratory.

The evaluators delivered sets of six Camera Operability Data Sheets (as shown in Appendix F) to the TMCs and UCI. Each data sheet in a set was for a different surveillance trailer. The District 12 and Anaheim TMCs were given loose-leaf books that contained multiple sets of data sheets separated by tabs to divide the hourly, daily, weekly, and monthly entries. Each data sheet contained two parts: Part I for prescribed camera image and control checks and Part II for notes. Part I contained nine columns: Column 1 for time of data entry; Column 2 for operator's initials; Column 3 for Mainline VIP Camera Image; Column 4 for Onramp VIP Camera Image; Column 5 for Surveillance Camera Image; Columns 6-8 for Surveillance Camera Control of Pan, Tilt, and Zoom; and Column 9 for Security Camera Image.

At each check, one row was completed on all six data sheets. For each camera image verification, a "check" mark (√) was placed in the corresponding data sheet cell if the camera image was available; otherwise an "x" mark was recorded in the cell. For each camera control verification, a "check" mark (√) was placed in the corresponding cell if the pan, tilt, and zoom for the color surveillance camera was operating. If one or more of the camera controls were not working, an "x" mark was recorded.

Data 2.1.1, camera image percent up time, was to be computed for each camera and for each location as the ratio of image "up" time to total time (sum of image "up" plus image "down" time). A check mark in a Camera Image Column was interpreted to mean that the associated camera image was present for the entire duration since the last check. An "x" mark in Camera Image Column was interpreted to mean that the associated camera image was "down" for the entire duration since the last check.

Data 2.1.2, camera control percent up time, was to be computed for each pan, tilt, and zoom control at each location. The camera control percent up time was defined as the ratio of control "up" time to total time (sum of "up" plus "down" time). A check mark in a Camera Control Column was interpreted to mean that pan, tilt, and zoom controls were operating for the entire duration since the last check. An "x" mark in a Camera Control Column was interpreted to mean that the camera control was not operational for the entire duration since the last check.

4.6.2.5 Data Collection Procedures for Performance Measure 2.2

Data 2.2.1 supports Performance Measure 2.2, camera image and control problems.

Data 2.2.1: Identity of camera image and control problems

Part II of each data sheet contained 20 numbered lines. When the first "x" mark was placed on Part I of the data sheet, a written statement was entered on Line 1 of Part II of the data sheet. This statement explained the nature of the problem associated with the first "x" mark denoted by “x1”. When the second "x" mark (reading from left to right and top to bottom) was placed on Part I of the data sheet, a written statement was entered on Line 2 of Part II of the data sheet. The second written statement explained the problem associated with the second "x" mark denoted by “x2”. The process continued with a note written for each "x" entry. These notes provided Data 2.2.1, identity of camera image and control problems.

4.6.2.6 Results from Data Gathered in Support of Performance Measures 2.1 and 2.2

The lessons learned from the data acquired at the TMCs in support of Performance Measures 2.1 and 2.2 are summarized as:

- Once the cameras and communications links were operational, camera control and picture quality were consistent from each venue. The camera control keyboard and other electronic assemblies used to control and select cameras appeared stable. Exceptions occurred when strong winds moved the antennas or the mast accidentally dropped because the locking pins were not fully extended.
- The transmission link should be checked over several days to ensure that the imagery is consistently good and relatively unaffected by weather and blowing trees.
- During periods of high winds, the antenna may move, thereby reducing signal to the relay site. In this case, realignment of the antenna is required.
- If the pins that lock the mast sections in place are not fully extended, several sections of the mast can fall and alter the field of view and calibration of the VIP.
- The stops on the surveillance camera should be adjusted during trailer setup to ensure that the camera can rotate to provide imagery of upstream and downstream traffic flow.
- Higher sensitivity color surveillance cameras should be sought to provide better imagery on poorly lighted roads.
- The pan and tilt assembly for the surveillance camera should be upgraded to a model that can support more weight. The manufacturer changed his specifications once the assembly was purchased and installed, and it was no longer recommended for the weight posed by the camera and all-weather enclosure. Therefore, the surveillance camera should not be tilted lower than the position necessary for horizontal viewing. If this limit is exceeded, it will not be possible to remotely raise the camera. In this event, the trailer mast will have to be lowered and the camera raised manually. Since the mast is moved in this procedure, the VIP camera alignment and calibration will also have to be verified.
- The sun shields should be extended to prevent glare at sunrise and sunset.
- To prevent vandalism to the security camera’s video and power cables, the cables should be protected, e.g., by placing them in conduit.

- The focus and f-stop on the security cameras have to be adjusted for optimum day and night use.
- At times, the graphical user interface (GUI) at the Caltrans ATMS stations failed to provide camera control. Control was still available, however, from the keyboard in the equipment rack located in the back room of the TMC.

4.6.2.7 Data Collection Procedures for Performance Measures 2.3 and 2.4

Data 2.3.1 and Data 2.4.1 were to be gathered concurrently in support of Performance Measures 2.3 and 2.4 and thus are described together.

Data 2.3.1: VIP percent up time

Data 2.4.1: Percent VIP data match video assessment

The evaluator also delivered sets of six VIP Believability Data Sheets (as shown in Appendix G), one for each of the six surveillance trailers, to the District 12 TMC. These data sheets were placed in the loose-leaf binder at the TMC. The data sheets contained two parts: Part I for prescribed VIP believability checks and Part II for notes. Part I contained eight columns: Column 1 for time of data entry; Column 2 for operator's initials; Column 3 for Mainline Loop ATMS 5-minute Averaged Volume, Occupancy, and Speed Data; Column 4 for Mainline VIP ATMS 5-minute Averaged Volume, Occupancy, and Speed Data; Column 5 for Mainline VIP Data Correspond to Visual Check of Volume, Occupancy, and Speed; Column 6 for Onramp Loop ATMS 5-min Averaged Data Entries of Demand, Passage, and Overflow; Column 7 for Onramp VIP ATMS 5-min Averaged Data Entries of Demand and Passage; and Column 8 for Onramp VIP Data Correspond to Visual Check of Demand and Passage.

One row on the Part I data sheet was to be used for each VIP check. For each data item requiring a numerical entry, a number was placed in the corresponding cell if the loop or VIP data were available. The Column 5 entry for VIP data correspondence to visual imagery simply required a "check" mark (√) if the data appeared consistent with the imagery; otherwise an "x" mark was recorded in this cell. The designated TMC operator determined whether the data were consistent with the imagery by answering the question: "If the VIP data were the only input available (no video), does it appear that the TMC would have reasonably accurate information to assess traffic conditions?" If the answer is "yes", a "check" (√) mark was placed in the Column 5. If the answer was "no", an "x" mark was entered. Problems were noted on Part II of the data sheet as before.

4.6.2.8 Results from Data Gathered in Support of Performance Measures 2.3 and 2.4

It soon became apparent that only three of the surveillance trailers were being polled by the ATMS, and even then, the polling was inconsistent. Therefore, performance measures 2.3 and 2.4 could not be recorded as originally envisioned. Instead, the technique of using two laptop computers connected directly to the 170 controllers in the surveillance trailers and roadside cabinets was used to compare ILD and VIP data. The laptop computers were used only at the three ramp meter evaluation sites. The VIP Believability Data Sheets were not used at the Anaheim or UCI-ITS Laboratory because data could not be received at these facilities.

VIP Percent Up Time (Data 2.3.1) – The percent of time that VIP data were observable at the District 12 TMC was low, approaching zero, because of the polling problem described above. However, observations from the evaluator and Caltrans confirm the VIP and its associated data were available 100 percent of the time at the surveillance trailers the field.

Percent VIP Data Match Video Assessment (Data 2.4.1) – The percent of match between freeway levels of service based on VIP data and video imagery could not be determined because VIP data were not received at the TMC. Instead, the two laptop computers were used to poll and record relevant ILD- and VIP-measured traffic flow parameters as described in Section 4.8.

4.6.2.9 Data Collection Procedures for Performance Measures 2.5 and 2.6

Data 2.5.1, Data 2.5.2, and Data 2.6.1 are gathered concurrently in support of Performance Measures 2.5 and 2.6 and thus are described together.

Data 2.5.1: Percent ramp signal correctly powered on/off

Data 2.5.2: Percent meter-on sign correctly powered on/off

Data 2.6.1: Percent proper vehicle presence response

The evaluator observed the operation of the ramp meter signals and coordinated the collection of test data. The evaluator and Caltrans personnel began ramp meter data collection at Tustin Ranch Road for a three day period and then proceeded to Jamboree Road for a similar time and finally to Grand Avenue. Originally, additional data collection was scheduled for each site. However, the time needed to identify and fix the early signal synchronization, yellow light at ramp turnon, and power system reliability problems shortened the time available for data collection.

Ramp Meter Operability Data Sheets (shown in Appendix H) were used to record information about the operation of the portable ramp meters. Each data sheet contained two parts: Part I for prescribed information and Part II for descriptions of any problems that arose. Part I contained seven columns: Column 1 for time of data entry, Column 2 for the operator's initials, Column 3 for Ramp Meter Signal On/Off Verification, Column 4 for Ramp Meter-on Sign On/Off Verification, Column 5 for Vehicle Present Treatment Confirmed, Column 6 for Vehicle Absent Treatment Confirmed, and Column 7 to note Visual Ramp Overflow.

One row was completed for each ramp meter check. For each power on/off verification within the ramp-metering period, the word "on" was placed in the corresponding cell if the designated item was turned on; otherwise an "x" mark was entered. Outside of the scheduled ramp meter period, the ramp signals and meter-on sign were to be off.

For each vehicle presence verification, a "check" (√) mark was placed in a cell in Column 5 if the signal head alternated between green and red when vehicles were present. Otherwise, an "x" mark was entered. For each vehicle absent verification, a "check" (√) mark was placed in a cell in Column 6 if the signal head remained red when vehicles were absent. If the signal did not remain red, an "x" mark was entered.

Percent ramp signal correctly powered on/off (Data 2.5.1) and percent meter-on sign correctly powered on/off (Data 2.5.2) were computed for each ramp meter as the ratio of "proper on/off state" time to total time (sum of ramp meter "proper on/off state" plus ramp meter "not proper on/off state" time). An “on” entry in any on/off column was interpreted to mean that the associated equipment was in the proper on/off state for the entire duration since the last check. An "x" mark in any on/off column was interpreted to mean that the associated equipment was not in the proper on/off state for the entire duration since the last check.

Percent proper vehicle presence response (Data 2.6.1) was computed for each ramp meter as the ratio of proper response time to total response time (sum of "proper response" time plus "not proper response" time). A “check” (√) mark in a Vehicle Present or Absent Treatment Column was interpreted to mean that the ramp meter response was proper for the entire duration since the last check. An "x" mark in a Vehicle Present or Absent Treatment Column meant that the ramp meter response was not proper for the entire duration since the last check.

4.6.2.10 Results from Data Gathered in Support of Performance Measure 2.5

Percent Signal Correctly Powered On/Off (Data 2.5.1) – The data sheets in Appendix H show that at Grand Avenue, the ramp signal was powered on correctly 100 percent of the time during scheduled ramp-metering periods. At other times, the signals were off. At Tustin Ranch Road, the ramp signal was also correctly on 100 percent of the time during scheduled ramp-metering periods and off at other times. At Jamboree Road, the ramp signal turned off one hour into an afternoon run on March 3, 1998 when the ramp meter generator tried to start and couldn’t. The radio receiver in the ramp trailer was not able to receive the commands from the surveillance trailer during the generator starting sequence. Based on the evaluation criteria, the Jamboree Road ramp trailer was correctly on and off for 25 of the 29 checks or 86 percent of the time it was monitored as part of the test.

Percent Meter-on Sign Correctly Powered On/Off (Data 2.5.2) – At Grand Avenue, the meter-on sign operated correctly 100 percent of the time. There was no permanent meter-on sign at Tustin Ranch Road. Therefore the portable meter-on sign was not installed either. The portable meter-on sign was not working at Jamboree Road because the radio transmitter/receiver combination between the ramp trailer and the sign did not have the transmission capabilities needed for the task. After the FOT was complete, new radios were installed, but their operation was not verified by the evaluator.

4.6.2.11 Results from Data Gathered in Support of Performance Measure 2.6

Percent Proper Vehicle Presence Response (Data 2.6.1) – Once the command synchronization problem between the surveillance and ramp meter trailers was fixed, the ramp signals generally followed the demand of the vehicles on the ramp. Exceptions were noted and linked to the color of the vehicles during the day and the relative location of headlight beams and the VIP detection zones at night. More data are required to fully quantify this phenomenon. When vehicles were missed and the ramp had two lanes or the camera field of view allowed VIP detection zones to be placed several car lengths upstream of the stop bar, the VIP generally detected another vehicle and changed the signal to green, allowing both to pass. Based on the evaluation criteria, the Grand Avenue ramp trailer correctly treated the presence of vehicles 44 out of 55 times or 80 percent of the time it was monitored as part of the test. The Tustin Ranch Road ramp trailer correctly treated the presence of vehicles 29 out of 37 times or 78 percent of the time it was monitored. The Jamboree Road ramp trailer correctly treated the presence of vehicles 25 out of 26 times or 96 percent of the time it was monitored.

4.6.2.12 Data Collection Procedures for Performance Measure 2.7

Data 2.7.1 supports Performance Measure 2.7, Ramp meter problems.

Data 2.7.1: Identity of ramp meter problems

Part II of each Ramp Meter Operability Data Sheet contained 20 numbered lines. When the first "x" mark, denoted by “x1”, was placed on Part I of a data sheet, a note was entered on Part II of the data sheet to explain the nature of the problem associated with “x1”. When the second "x" mark, denoted by “x2” (reading from left to right and top to bottom), was placed on Part I of the data sheet, an explanation was likewise entered on Part II of the data sheet. The process continued with an explanation provided for each "x" mark. Another source of information about ramp meter issues related to VIP detection zones was the notes taken by the evaluator. These sources of information provided Data 2.7.1, identity of ramp meter problems.

4.6.2.13 Results from Data Gathered in Support of Performance Measure 2.7

The comments and problems noted on the Ramp Meter Operability Data Sheets included:

- Daytime vehicle detection on ramps was sometimes affected by the relative color of the vehicle with respect to the road surface;
- Nighttime vehicle detection on ramps was affected by alignment of VIP detection zones and vehicle headlight beams;
- At Grand Avenue, the signals followed the 170 controller commands after the delay on the digital input board was changed to 100 milliseconds from 5 seconds. However, the VIP detectors continued to miss vehicles from time to time;
- Ramp overflow detection by VIPs will most likely require an additional camera to detect vehicles at the ramp entrance;
- The ramp trailer generator at Jamboree Road could not start on demand, causing the ramp signal to turn off;
- Faulty optical isolators caused dim signals and bleed-through to light a signal that should not be lighted;
- The need for a better radio link between ramp meter trailers and meter-on signs was verified.

A summary of the data recorded in the evaluator’s notes appears in Table 4-8.

Table 4-8. Issues concerning VIP detection zones used for ramp signal control

Site	Date	Issue
Grand Avenue and Tustin Ranch Road	Jan. 28, 1998 a.m.	Missing some vehicle detections on the ramp; more dark vehicles missed than lighter colored ones. Causes longer queues. At Grand Avenue, missing about 1-2 cars every 1/2 hour. Missing more cars at Tustin Ranch Road; increased metering rate to 12 veh/min from 10 to help reduce queue at Tustin Ranch.

Tustin Ranch Road	Jan. 28, 1998 a.m.	No luminaries. Therefore, ramp is very dark before dawn. Auto headlights trigger the VIP demand detector long before the vehicle arrives at the detector. Thus, there is no delay for vehicles on the ramp as the signal has already turned green.
Jamboree Road	Feb. 5, 1998	Because the surveillance trailer is close to the ramp, the VIP camera's field of view does not include a count zone for the number of vehicles entering the mainline. As at the other sites, it cannot create a queue overflow detector either. Another limitation at Jamboree Road is that the demand zone cannot be extended upstream from the signal to detect vehicles that may stop more than one car length from the signal. However, even with these limitations, the mobile ramp signal appears to function adequately at this site.
Tustin Ranch Road	March 4, 1998 p.m.	Cargo container truck at stop bar did not get a green signal. Neither the aluminum-colored truck body not its headlights triggered the demand detector.
Tustin Ranch Road	March 5, 1998 7 a.m.	Leading dark-colored auto followed by white auto were not detected by demand detector. Signal remained red and was manually changed to green ball six minutes later to relieve the queue. Used supervisory computer to add more demand detectors upstream of the stop bar. The supervisory computer showed that the existing detectors were directional, whereas the detectors at the other sites were not. Changed the detectors to non-directional (requires suspending shadow processing by AutoScope) and added two additional demand detectors upstream of the original ones. The two added detectors were in the shape of an X. The total number of demand detectors in the right ramp lane was now five. All were connected with OR logic. The five detectors filled the entire field of view of the camera.
Grand Avenue	March 5, 1998 a.m.	Vehicles appear to be waiting longer than 2 seconds for a green ball. In addition, green does not change to red immediately. Called software subcontractor to investigate the problem; changed delay on digital input board to 100 msec. Also missing calls, e.g., a black vehicle in the left ramp lane did not get a green ball after 6-8 seconds.

4.6.3 Test Objective 3 - Freeway Deployment Institutional Issues

The evaluation of freeway deployment institutional issues had as its objective the identification of the advantages, disadvantages, and costs related to using the surveillance and ramp meter trailers for traffic management operations and research.

4.6.3.1 Measures of Performance

The measures of performance for this assessment are:

- Measure 3.1: Advantages of freeway deployment
- Measure 3.2: Disadvantages of freeway deployment
- Measure 3.3: Costs of freeway deployment.

4.6.3.2 Test Data

The data collected in support of each performance measure are:

Measure 3.1: Advantages of freeway deployment

Data 3.1.1: Identity of advantages of freeway deployment

Measure 3.2: Disadvantages of freeway deployment

Data 3.2.1: Identity of disadvantages of freeway deployment

Measure 3.3: Costs of freeway deployment

Data 3.3.1: Identity of cost items related to freeway deployment.

4.6.3.3 Data Collection Procedure and Results

The data collected in support of Objective 3 are described below.

Data 3.1.1: Identity of advantages of freeway deployment

Institutional issues that concerned freeway deployment were discussed for many months prior to the test and led to a preliminary list of freeway deployment advantages:

- Advantage F1: Allows remote surveillance of freeway mainline
- Advantage F2: Allows remote surveillance of freeway onramps
- Advantage F3: Facilitates coordination between Caltrans Operations and Caltrans Maintenance Divisions.

The evaluator requested written statements from the lead Caltrans personnel involved with the I-5 Test confirming the identity the advantages of deploying the trailers in a freeway setting for traffic management operations and research. The result of this activity was Data 3.1.1, the identity of the advantages of freeway deployment.

Data 3.2.1: Identity of disadvantages of freeway deployment

As a result of the institutional issue discussions, the freeway deployment disadvantages were identified as:

- Disadvantage F1: Requires complex intra-agency coordination
- Disadvantage F2: Represents potential roadway hazard
- Disadvantage F3: Requires state to acquire new expertise
- Disadvantage F4: Requires special security arrangements.

The evaluator requested written statements from the lead Caltrans personnel confirming the identities of the disadvantages. The result of this activity was Data 3.2.1, the identity of the disadvantages of resource sharing.

Data 3.3.1: Identity of cost items related to freeway deployment

As a result of the institutional issue discussions, the initial list of cost items related to freeway deployment was identified as:

- Cost Item F1: Trailer movement and storage
- Cost Item F2: Trailer fuel and maintenance
- Cost Item F3: TMC equipment installation
- Cost Item F4: Training of Caltrans personnel.

The evaluator requested written statements from the lead Caltrans personnel confirming that this list correctly identified the cost items. The costs to date and those anticipated for future trailer use were also requested. The result of this activity was Data 3.3.1, the identity of the cost items related to freeway deployment.

LPG Fuel Consumption (Cost Item F2) – The cost of liquid propane fuel for the generators in the surveillance trailers was estimated from the generator-use logs kept in the surveillance trailers. The logs (included in Appendix I) indicated when the liquid propane gas (LPG) tanks were refilled and noted the generator in-use hours at which this event occurred. Unfortunately, the entries do not allow an accurate assessment of the fuel use per hour of generator ontime to be made as may be seen from the scatter in Table 4-9. The capacity of the tank in the surveillance trailer is 88 gallons of liquid. (The capacity of the tank in the ramp meter trailer is 60 gallons of liquid.) LPG fuel cost was approximately $1.75/gallon. Assuming the most likely estimates of LPG consumption are represented by the values under 0.01136 tank/hr (1 gallon/hr), the average LPG used by a surveillance trailer is approximately 0.00522 tank/hr or 0.460 gallon/hr. Under this assumption, the estimated cost of LPG is $0.80/hr for surveillance trailer operation. If all the data in Table 4-9 are averaged, the LPG use is 0.01116 tank/hr (0.982 gallon/hr) or $1.72/hr.

Table 4-9. LPG fuel consumption by the surveillance trailers

Site	Date	Hours	Delta Hours	Fuel Level	Delta Fuel	Approximate Fuel Volume/Operating Hour
Main Place	11/10/97	1058.6		1/2		
Surveillance Trailer	12/4/97	1110.2	51.6	3/4	1/4	0.00484 tank/hr=0.426g/hr
Grand Avenue	10/8/97	552.6		3/4		
Surveillance Trailer	11/20/97	671.9	119.3	7/16 (?)	5/16	0.00262 tank/hr=0.231g/hr
	12/2/97	699.3		1/4		
	12/4/97	705.1	5.8	3/4	1/2	0.08621 tank/hr=7.586g/hr
	3/16/98	1322.7		3/4		
	5/5/98	1600.3	277.6	0	3/4	0.00270 tank/hr=0.238g/hr
First Street	9/16/97	1124.2		1/2		
Surveillance Trailer	10/7/97	1159.7	35.5	3/4	1/4	0.00714 tank/hr=0.629g/hr
	11/4/97	1210.8	51.1	1/2	1/4	0.00489 tank/hr=0.431g/hr
	1/8/98	1306.1		7/16 (?)		
	1/19/98	1329.8	23.7	3/4	5/16	0.01319 tank/hr=1.160g/hr
	1/23/98	1415.6		3/4		
	2/11/98	1572.9	157.3	1/4	1/2	0.00318 tank/hr=0.280g/hr
Tustin Ranch Road	1/19/98	1063.5		5/8		
Surveillance Trailer	1/22/98	1125.6	62.1	0	5/8	0.01006 tank/hr=0.885g/hr
Jamboree Road	3/25/98	1409.2	126.4	3/4		
Surveillance Trailer	4/9/98	1449.1	39.9	1/2	1/4	0.00627 tank/hr=0.551g/hr
Culver Drive	6/19/97	718.0		3/4		
Surveillance Trailer	6/24/97	740.4	22.4	5/8	1/8	0.00558 tank/hr=0.491g/hr
	6/26/97	760.7	20.3	3/4	1/8	0.00616 tank/hr=0.541g/hr
	7/8/97	790.5	29.8	5/8	1/8	0.00419 tank/hr=0.369g/hr
	7/10/97	811.3	20.8	3/4	1/8	0.00601 tank/hr=0.529g/hr
	7/15/97	869.4	58.1	1/2	1/4	0.00430 tank/hr=0.379g/hr

4.6.3.4 Other Lessons Learned from Test Objective 3

Summaries of other lessons learned from interviews conducted in support of Test Objective 3 are:

GUI Trailer Location Updates - Whenever a trailer is moved to a new freeway location, the field device database on the TMC GUI must be updated to reflect the new trailer location. If not, the trailer icon on the TMC map display will not reflect the actual trailer location, and will potentially confuse personnel as to the true location of the trailer. However, if the trailer location icon is updated, the data gathered at the previous trailer location are automatically removed from the database. This may present a problem if it is necessary to retrieve the previous data later. A solution may be to add alpha characters or in some other way modify the trailer name each time the trailer is moved. In this manner, the computer program will think a new trailer has been added to the array. The drawback with this approach is that the display will eventually become cluttered with icons that represent nonexistent trailer locations.

GUI Trailer Cluster Icons - The trailer location icon cluster on the TMC GUI consists of many closely spaced camera and detector icons. District 12 TMC personnel report difficulty in selecting the one icon they need from among the many in the cluster. It has been suggested that a single icon representing the trailer replace this cluster of icons. A mouse click to the new icon would trigger the image from the pan-tilt-zoom surveillance camera on the trailer. Buttons on this initial video window would then allow the other cameras and detector stations to be selected.

Construction Zones - Construction at the Katella Avenue interchange of I-5 began in the Spring of 1998. Freeway widening and the Disneyland expansion are expected to have a negative impact on traffic flow through Spring of 1999. Both the District 12 and Anaheim TMCs have identified this location as a high priority site for temporary surveillance. Placing a surveillance trailer in this area has been frustrated by lack of commercial power and frequent changes to the configuration of the construction site. As of August 1998, the Caltrans contractors had been unable to accommodate a surveillance trailer at the Katella Avenue interchange. It has been suggested that construction zone dust and vibrations may compromise trailer operations during excavation activities, but these concerns have not been substantiated.

Traffic Management Plan - Each construction project is accompanied by a formal traffic management plan. If the surveillance trailers are included as part of a future construction zone traffic management plan, the contractor would be obligated to accommodate the trailer and protect it. The contractor would have to determine the cost to protect the trailer and include such costs in his bid. For example, the contractor could place K-rail around the trailer to protect it from being hit by vehicles. The contractor would also have to remove graffiti from the *K*-rail within 48 hours.

Ramp Meter Trailers - There has been no experience to date using the ramp meter trailers in construction zones. One Caltrans resident engineer explained that Caltrans doesn’t want ramp metering in construction zones because they cannot maintain the system and it will not help the mainline (which normally is congested in construction zones anyway). There appears to be no current interest in using the ramp meter trailers for a temporary ramp meter installation. One Caltrans ramp meter engineer explained that Caltrans would prefer a permanent ramp meter installation to a temporary installation in order to ensure driver acceptance and compliance. Anaheim is open to the idea of using the ramp meter trailers for special event traffic management. It has been suggested that the ramp meter trailers be used to meter parking lot egress.

Ramp Meter Timing Plan Development - Caltrans ramp meter engineers are interested in using the surveillance trailers to support the development of ramp meter timing plans. To develop a ramp meter plan, the engineers need to identify the controlling bottleneck. This requires a thorough analysis of traffic count data that may not be available in some locations. Furthermore, manual traffic counts are labor intensive and, therefore, expensive. The surveillance trailers could be used to collect count data that would otherwise be unavailable, thereby supporting the development of ramp meter plans.

4.6.4 Test Objective 4 - Information Sharing Institutional Issues

The objective of evaluating institutional issues associated with information sharing was to identify the advantages, disadvantages, and cost items related to Caltrans sharing freeway traffic video and data with the Anaheim TMC and the UCI-ITS Laboratory over the wireless communications network.

4.6.4.1 Measures of Performance

The measures of performance for this assessment are:

- Measure 4.1: Advantages of sharing freeway video and data
- Measure 4.2: Disadvantages of sharing freeway video and data
- Measure 4.3: Costs of sharing freeway video and data.

4.6.4.2 Test Data

The data collected in support of each performance measure are:

Measure 4.1: Advantages of freeway video and data sharing

Data 4.1.1: Identity of advantages of sharing freeway video and data

Measure 4.2: Disadvantages of freeway video and data sharing

Data 4.2.1: Identity of disadvantages of sharing freeway video and data

Measure 4.3: Costs of freeway video and data sharing

Data 4.3.1: Identity of cost items related to sharing freeway video and data

4.6.4.3 Data Collection Procedure and Results

The data collected in support of Objective 4 are described below.

Data 4.1.1: Identity of advantages of sharing freeway video and data

Institutional issues concerning the sharing of freeway video and data were discussed for many months prior to the test, resulting in a preliminary list of advantages. These are:

- Advantage D1: Allows the Anaheim TMC to better manage city operations in the vicinity of I-5
- Advantage D2: Allows the UCI-ITS Laboratory to readily incorporate real-time freeway data into ongoing transportation research
- Advantage D3: Facilitates inter-agency cooperation between Caltrans District 12, Anaheim TMC, and UCI-ITS Laboratory.

The evaluator requested written statements from Caltrans, Anaheim, and UCI personnel involved with the I-5 Test confirming this list correctly identified the advantages of sharing freeway video and data among Caltrans, Anaheim, and the UCI-ITS Laboratory. The result of this activity was Data 4.1.1, the identity of the advantages of sharing freeway video and data.

Data 4.2.1: Identity of disadvantages of freeway video and data sharing

As a result of the institutional issue discussions, the disadvantages of sharing freeway video and data were identified as:

- Disadvantage D1: Requires operators at different facilities to share common video controls
- Disadvantage D2: Requires Anaheim TMC operators and UCI-ITS personnel to acquire new expertise
- Disadvantage D3: Requires Anaheim and UCI to purchase a supervisory computer or other software to display the VIP data.

The evaluator requested written statements from Caltrans, Anaheim, and UCI personnel confirming this list correctly identified the disadvantages of sharing freeway video and data among the three organizations. The result of this activity was Data 4.2.1, the identity of the disadvantages of sharing freeway video and data.

Data 4.3.1: Identity of cost items related to sharing freeway video and data

As a result of the institutional issue discussions, cost items related to sharing freeway video and data were assembled as:

- Cost Item D2: Anaheim TMC and UCI-ITS Laboratory equipment installation
- Cost Item D1: Public utilities and maintenance costs.

The evaluator requested written statements from Caltrans, Anaheim, and UCI personnel to confirm the list identified the cost items associated with sharing freeway video and data among Caltrans, Anaheim, and the UCI-ITS Laboratory. Data quantifying the costs expended to date and those anticipated for future trailer use were also requested. The result of this activity was Data 4.3.1, the identity of the cost items related to the sharing of freeway video and data.

4.6.4.4 Other Lessons Learned from Test Objective 4

Summaries of other lessons learned from interviews conducted in support of Test Objective 4 are:

Video Sharing - Shared control of a surveillance camera by allied agencies working from different sites is customary. This occurs whenever there is an incident within range of a shared camera. District 12 TMC personnel report that primary control typically goes to whichever agency has superior camera control capability. For example, if another agency has better control of a given camera, the District 12 TMC will let the other agency control it. If the District 12 TMC wants a different view, they call the other agency and ask the camera to be moved.

Research - Researchers at the UCI-ITS laboratory are also interested in using the surveillance trailers to fill gaps in the available inductive loop database. To date, none of the UCI-ITS researchers have used the trailers to gather data. The current surveillance trailer design uses a 170 controller to poll the VIP for data at 30-second intervals.

Therefore, data at less than 30-second intervals (of interest to some researchers) are not available.

4.7 Pilot Tests

Two pilot tests were planned in conjunction with the I-5 Test, the Pilot Video Image Processor Performance Assessment and the Pilot Spread Spectrum Radio Performance Assessment. The Video Image Processor Assessment was designed to measure the relative accuracy of the VIP with respect to the ILD in detecting individual vehicles. A form of this test was conducted when the laptop computers were used to poll and record the data from the 170 controllers. The differences between this and the pilot test were that 30-second vehicle counts are output by the 170 instead of individual vehicle counts, and simultaneous video of the traffic flow was not recorded as “ground truth” data. The Spread Spectrum Radio Assessment was designed to measure how many information packets were dropped during transmission from the surveillance trailer to the District 12 TMC. Both required the data logger. Repeated attempts were made by Caltrans to have their contractors, first Hughes and then Iron Mountain Systems, complete the design and programming of the data loggers. However, these tasks could not be completed in the time allotted for the FOT. The pilot test procedures are described in the Evaluation Plan.

4.8 Quantitative Data Acquisition and Analysis Procedures for Performance Measure 2.4 (VIP Data Believability)

The inability of the District 12 ATMS to access the VIP data in the surveillance trailers led to the dual laptop computers being used in the field to record the inductive loop and VIP volume and occupancy data. Since the primary purpose of the FOT was to evaluate the ability of the mobile trailers to support ramp metering, the speed data calculated by the 170 controllers in the field were not analyzed. Doing so would have increased the complexity of the analysis, as special software would have to be written. The comparison of the ILD- and VIP-produced speeds would have been performed had the ATMS software been able to access the 170 controller connected to the VIP. Instead, the procedures below were developed to gather data to support Performance Measure 2.4, VIP data believability.

Two to three days of data were collected at each of the three ramp meter trailer locations, as shown in Table 4-10. No rain or incidents occurred at the evaluation sites during these data collection periods.

The recording of data by the laptop computers is illustrated in Figure 4-21. The laptop that polled the 170 controller connected to the VIP was placed in the trailer. The other laptop was located in the roadside cabinet that housed the 170 controller that processed the ILD data. The laptops simulated the polling and data capture features of the ATMS computer system at District 12, which was not available during the FOT.

Table 4-10. Ramp meter data collection times

Site	AM Data Collection Date and Time Interval		PM Data Collection Date and Time Interval
Tustin Ranch	March 5, 1998	6:15-9:30	—

Road	March 9, 1998	6:15-9:30	March 9, 1998	14:15-19:00
	March 10, 1998	6:15-9:45	March 10, 1998	16:15-19:00
Grand Avenue	April 14, 1998	6:15-9:30	April 14, 1998	14:45-19:00
	April 16, 1998	6:15-9:30	April 16, 1998	16:30-19:00
Jamboree Road	—		March 11, 1998	15:15-19:00
	March 12, 1998	6:15-9:30	March 12, 1998	15:15-19:00
	March 13, 1998	6:15-9:45	March 13, 1998	15:15-19:00

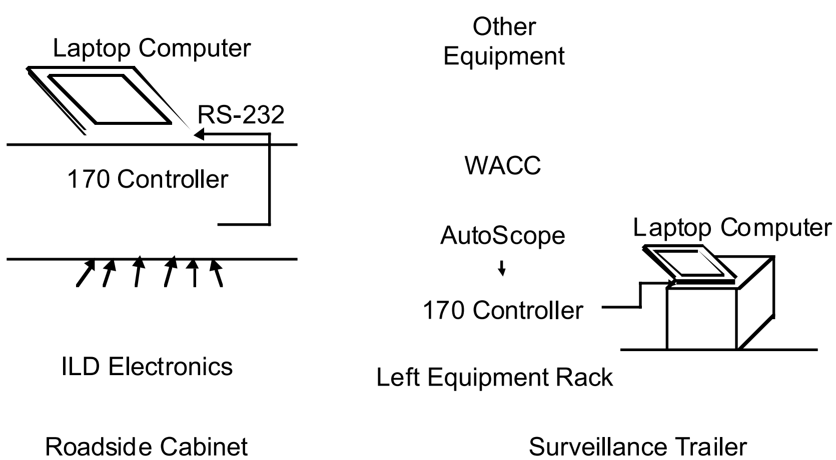


Figure 4-21. ILD and VIP data recording from 170 controllers using laptop computers

The clocks in both laptops were synchronized to within one 30-second polling interval. The clock in the 170 controller in the surveillance trailer drifted several minutes during a 4-hour run because of the non-ideal frequency stabilization that was characteristic of the portable electric power generation system. The laptop computer sent a synchronization signal to the 170 every hour in order to compensate for 170-clock drift.

4.8.1 Mainline Occupancy and Volume

ILD data were recorded from the inductive loops already installed in the mainline lanes. VIP data were obtained from the AutoScope 2004 VIP (part of the equipment in the surveillance trailer) using the loop emulation output. One of the black and white Burle cameras that supplied imagery to the AutoScope VIP was pointed at the mainline, and the other was pointed at the onramp to view the ramp signal area.
The data from all test runs are reported chronologically in a similar manner, namely (1) a series of plots of lane-by-lane occupancy and volume data versus time, (2) combined occupancy and volume data over all lanes reporting good data with respect to time,

(3) averages of occupancy and volume data for all lanes reporting good data, and (4) percent differences in average occupancy and total volume between the VIP and ILD measurements. Good data are ILD and VIP data that are not reported by the 170 controllers (that process the data) as suspect or affected by a detector malfunction. The first series of plots showing the lane-by-lane time series data are presented for most tests, even if only one of the ILD or the VIP data sets is good. However, the information in the second through fourth data presentations is only shown for lanes where both good ILD and VIP data were recorded. Data are omitted from further analysis at time intervals when one detector reports good data, but the second detector reports suspect data or a detector malfunction. This is done to eliminate biases from the average occupancy and volume values that are reported. ILD and VIP data were collected over the first five lanes of the mainline, with the lane closest to the shoulder designated Lane 5. Data were not collected in the high occupancy vehicle lanes that were located to the left of the leftmost general vehicle lane (designated Lane 1).

Thirty-second data (polled from the 170 controller) integrated over a 15-minute interval are plotted in the figures in the first and second data presentations. The 15-minute averaged data were used for analysis because the data file that was output by the data-polling program could not directly write the data to an electronic computer file. Therefore, the data had to be printed and then manually re-entered into a spread sheet program. Thus, using 15-minute data made the manual re-entry task manageable for the multi-hour evaluation runs.

After the data from the individual runs are described, the overall averages of the percent differences in lane occupancies and volumes over the 14 data runs are presented. These averages describe the expected performance of the trailer system in measuring traffic volume for the ramp-metering application.

4.8.2 Ramp Signal Demand and Metering Rate

In addition to the mainline occupancies and volumes, the laptop computers also recorded ILD and VIP data from the demand, passage, on, and queue detectors on the I-5 Freeway onramps. ILD data were recorded from the inductive loops already installed on the ramps. VIP data were obtained from the AutoScope using imagery from the Burle camera that was pointed at the onramp. Only the ILD queue detectors were monitored. Their location at the entrance to the ramp made it impossible for the Burle camera to view this area, since the camera was pointed near the ramp signal (that was closer to the ramp exit onto the mainline than to the ramp entrance). Hence, a VIP ramp queue detector could not be implemented. The analyzed data from the ILD and VIP detectors included metering rate used, local responsive rate, time-of-day rate, and ramp demand occupancy and volume. At the Tustin Ranch Road and Jamboree Road sites, long queues formed when traffic backed up to the start of the onramps. In order to try to minimize the queue length, the metering rate on the VIP 170 controller was set to the maximum value permitted in the time-of-day tables. The time-of-day rate in the ILD 170 controller was not adjusted since we did not want to disturb the permanent metering rate of the ramp. Therefore, the time-of-day meter rate plots and the meter rate used plots in Figures D-108 through D-135 show different values for the ILD and VIP detectors. A long queue was not a consideration at the Grand Avenue site and, consequently, the ILD and VIP time-of-day rates were the same at this venue.

The local responsive ramp-metering algorithm that resides in the 170 controllers at the onramps works as follows. First, a time-of-day (TOD) rate is programmed into the 170 controller. This rate may be either (1) entered manually by a traffic engineer into the 170 controller in the field, (2) sent by a TMC operator to the 170 in the field, or (3) sent by area engineers from their office to the 170 in the field. Second, a critical value for the average 3-minute mainline volume/lane (currently 75 vehicles) and a critical value for the average 1-minute mainline occupancy/lane (currently 20 percent) are entered into the 170 controller. Third, a local responsive (LR) rate based on mainline volume or mainline occupancy is calculated. The LR rate based on mainline volume is given by

$$\text{LR Rate}_V = \frac{\text{Mainline total volume}}{\text{Number of lanes}} - \text{Critical volume.} \tag{4-1}$$

The LR rate based on mainline occupancy is given by

$$\text{LR Rate}_O = \text{Average occupancy} - \text{Critical occupancy.} \tag{4-2}$$

Fourth, if either the locally measured mainline volume or occupancy is less than the critical value, then the local responsive meter rate is used, provided the LR rate is greater than the value in the TOD table. If the TOD rate is larger, then it is used. If the locally measured mainline volume or occupancy is greater than the critical value, then the TOD rate is also used.

The total mainline volume listed on the ramp demand and metering rate reports does not represent the same total mainline volume parameter listed on the mainline occupancy and volume reports. The mainline volume shown on the ramp data report is the value output by the 170 controller before adjustment for suspect data or malfunctioning detectors. The value on the mainline data report is the adjusted value. The adjusted value is found as follows. Suppose that the mainline consists of 5 general purpose vehicle lanes and that the Lane 5 detectors are not operational, but the Lane 1 through Lane 4 detectors are working properly. The adjusted total mainline volume is calculated by summing the volumes from Lanes 1 through 4 and multiplying the result by 5/4. The local responsive ramp-metering algorithm uses the adjusted mainline total volume.

Section 4.9 describes the results of the mainline occupancy and volume data analysis. Section 4.10 describes the results of the ramp signal demand and metering rate analysis.

4.9 Mainline Occupancy and Volume Data Analysis

The following sections describe the rush hour interval occupancy and volume results obtained at each morning and afternoon evaluation run at which 170-controller polling data were recorded on the laptop computers.

4.9.1 Tustin Ranch Road AM Rush Hour Occupancy and Volume Data for 3/5/98

Comparisons of the March 5, 1998 lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site are displayed in Figures J-1 to J-4, respectively, of Appendix J. The data are plotted as a function of time for the 6:15 to 9:30 morning rush hours.

The 170 computers that processed the ILD and VIP detector inputs reported a malfunction during the acquisition or processing of all of the ILD data and most of the VIP data from Lane 5, the lane closest to the right shoulder, as shown in Tables J-1 and J-2 of Appendix J. Hence, Lane 5 data are not plotted for the Tustin Ranch Road site. Figure J-1 does not contain ILD data as the 170 controller reported suspect data or detector malfunctioning for Lane 1 during the recording interval. Figures J-2 through J-4 show that the Lane 2 through Lane 4 lane occupancies and volumes from the ILDs and VIP generally track one another over time.

Figure J-5 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-6 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 2 to 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-7 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 2 to 4 combined. The ILD value is used as the reference for the percent difference calculation. The VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes.

Two effects contribute to the less than optimal performance of the VIP compared with the inductive loops, especially in lanes further from the trailer location. Both effects are caused by the relatively low operational height of the VIP cameras above the road surface [approximately 32 feet (9.8 meters)] as constrained by the height of the fully extended mast on the surveillance trailer. Tall vehicles, such as large commercial trucks, that project their image into adjacent lanes produce the first effect. The VIP detector zones in the adjacent lanes detect the truck as if it was actually traveling in those lanes. Depending on the location of the surveillance trailer with respect to the roadway, the tall vehicle can project its image into 1, 2, or 3 adjacent lanes. Thus, the VIP will overcount vehicles if this effect is present. The second factor that degrades VIP performance is blockage of shorter vehicles, such as passenger cars, in the lanes further from the camera by taller vehicles traveling in the lanes closer to the camera. This effect appears to be less prevalent than the detection of a tall vehicle in more than one lane.

Because of these two effects, it was anticipated that the vehicle counts and lane occupancies calculated by the VIP would be closest to the values calculated from the inductive loops in the lane nearest the surveillance trailer containing the camera used with the VIP, i.e., the rightmost lane. In this lane, there would be no false images of tall vehicles or blockage of short vehicles by the taller ones. This premise is somewhat substantiated by the data in Figure J-7. Data in other runs and at other sites support this premise to a greater degree. The smallest percent differences of VIP data with respect to ILD data occur in Lanes 2 and 4. For Lane 4, the percent difference is –37.4 for the total volume (indicating significant overcounting by the VIP) and -3.8 for the occupancy averaged over the morning rush-hour period. For Lane 2, the percent difference is –37.3 for the total volume (significant overcounting by the VIP) and –6.0 for the occupancy. Lane 3 (the middle freeway lane) displayed the greatest percent differences, apparently from the domination of vehicle image projection into this lane. Here the percent differences were –61.7 for the volume and –28.0 for the occupancy. Over the combination of Lanes 2 through 4, the percent differences were –44.4 for volume and –10.8 for occupancy.

4.9.2 Tustin Ranch Road AM Rush Hour Occupancy and Volume Data for 3/9/98

Figures J-8 to J-11 compare the March 9, 1998 lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site. The data are plotted as a function of time for the 6:15 to 9:30 morning rush hours.

The 170 computers that processed the ILD and VIP detector inputs reported a malfunction during the acquisition or processing of all of the ILD data and most of the VIP data from Lane 5 as shown in Tables J-3 and J-4. Hence, Lane 5 data are not plotted. Figure J-8 does not contain ILD data as the 170 controller reported suspect data or detector malfunctioning for Lane 1 during the recording interval. Figures J-9 through J-11 show that the Lane 2 through Lane 4 lane occupancies and volumes from the ILDs and VIP generally track one another over time.

Figure J-12 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-13 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 2 to 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-14 displays the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 2 to 4 combined. The VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes. In Lane 4, the percent difference of the VIP data with respect to the ILD data is -2.1 for the total volume (slight overcounting by the VIP) and -43.5 for the occupancy averaged over the morning rush-hour period. It appeared that Lane 3 (the middle freeway lane) displayed the greatest percent differences, apparently from the domination of vehicle image projection into this lane. The Lane 2 percent differences are again similar to those of Lane 4. Over the combination of Lanes 2 through 4, the -50 percent difference in volume indicated significant overcounting by the VIP. The –10.3 percent difference in occupancy was in the small range.

4.9.3 Tustin Ranch Road PM Rush Hour Occupancy and Volume Data for 3/9/98

Figures J-15 to J-18 display the March 9, 1988 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site. These data were acquired from 14:15 to 19:00 hours. In this test, the 170 computer that processed the ILD detector inputs reported a malfunction during the acquisition or processing of data from Lane 5 as shown in Tables J-5 and J-6. Similar error reports were obtained for most of the VIP data from Lane 5. Hence, Lane 5 data are not plotted for this run either. Figures J-15 through J-18 do not contain ILD or VIP data between 14:15 to 15:45 hours because the VIP data were suspect or the detector was reported as malfunctioning during these times. The plot of Lane 1 data begins at 17:45 hours, as this is when both good ILD and VIP data were recorded. Generally, the lane occupancy and volumes from the ILDs and VIP track one another over time.

Figure J-19 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-20 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1 to 4 combined and Lanes 2 to 4 combined. Figure J-21 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 to 4 combined and Lanes 2 to 4 combined. In this data set, the percent differences between the VIP and ILD occupancies and volumes are of the same order of magnitude. The percent differences for Lane 4 (the lane closest to the surveillance trailer and camera) are smallest. The percent difference of the VIP data with respect to the ILD data is -48.5 for the total volume (significant overcounting by the VIP) and -52.8 for the occupancy in Lane 4 averaged over the afternoon rush-hour period. Lane 1 (the leftmost freeway lane designated for general traffic) displayed the greatest percent differences, apparently from having the most vehicle image projection into this lane.[6]

4.9.4 Tustin Ranch Road AM Rush Hour Occupancy and Volume Data for 3/10/98

Figures J-22 to J-25 compare the March 10, 1998 lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site for the morning rush from 6:15 to 9:45 hours. The 170 computers that processed the ILD and VIP detector inputs reported malfunctions during the acquisition or processing of data from Lane 5 as shown in Tables J-7 and J-8. Hence, Lane 5 data are not plotted for the Tustin Ranch Road site. Figure J-22 does not contain ILD data as the 170 controller reported suspect data or detector malfunctioning for Lane 1 during the recording interval. Figures J-23 through J-25 show that the lane occupancy and volumes from the ILDs and VIP generally track one another over time.

Figure J-26 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. Again, the two sets of ILD and VIP values track one another well. Figure J-27 contains the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are displayed for each lane and for

6. Lane 1 ILD data were not available for the morning rush hour run on this day. Thus, Lane 3 data were reported to have the largest percent difference for the morning run.

Lanes 2 to 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-28 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 2 to 4 combined. As in the March 9 data set, the VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes.

The percent differences in occupancy and volume measurements for Lane 4 (the lane closest to the surveillance trailer and camera) are smallest, although there is significant overcounting by the VIP, even in Lane 4. Lane 5 comparisons are not available because of ILD malfunctioning in this lane. The percent difference of the Lane 4 VIP data with respect to the ILD data is -35.2 for total volume and -3.9 for occupancy averaged over the morning rush-hour period. Lane 3 (the middle freeway lane) again displayed the greatest percent differences during the morning run, apparently caused by vehicle image projection.

4.9.5 Tustin Ranch Road PM Rush Hour Occupancy and Volume Data for 3/10/98

Figures J-29 to J-32 display the March 10, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 4 of the I-5 mainline at the Tustin Ranch Road site. These data were acquired from 16:15 to 19:00 hours. In this run, the 170 computer that processed the ILD detector inputs reported a malfunction during the acquisition or processing of data from Lane 5 as shown in Tables J-9 and J-10. Similar error reports were obtained for most of the VIP data from Lane 5. Hence, Lane 5 data are not plotted for this run either. As in the other runs, lane occupancies and volumes from the ILDs and VIP track one another over time.

Figure J-33 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 2 to 4 as a function of time. The two sets of ILD and VIP values track one another well. Although some ILD data were obtained from Lane 1, the accuracy of these values and the corresponding VIP values are questionable as shown later by the large percent differences recorded in Figure J-35. Figure J-34 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 2 to 4 combined (the lanes reporting good data for both the ILDs and VIP). Only VIP data are available for Lane 5 as noted earlier.

Figure J-35 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 2 to 4 combined. The percent differences between the VIP and ILD occupancies and volumes are of the same order of magnitude as in the afternoon run of March 9. Again, the percent differences for Lane 4 (the lane closest to the surveillance trailer and camera) are smallest, although there is significant overcounting by the VIP. The percent difference of the VIP volume data with respect to the ILD data is -47.0 in Lane 4 averaged over the afternoon rush-hour period. The percent difference for the occupancy is -44.7 in Lane 4. Lane 1 (the leftmost freeway lane designated for general traffic) displayed the greatest percent differences, apparently from the effects of vehicle image projection on the VIP measurements.[7] The Lane 1 ILD suspect data or detector malfunction reports from earlier in the afternoon also cast some uncertainty into the accuracy of the ILD data.

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7. Lane 1 ILD data were not available for the morning rush hour run. Thus, Lane 3 data were reported to have the largest percent difference for the morning run.

4.9.6 Jamboree Road PM Rush Hour Occupancy and Volume Data for 3/11/98

Figures J-36 to J-40 display the March 11, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5, respectively, of the I-5 mainline at the Jamboree Road site. These data were acquired from 15:15 to 19:00 hours. In this afternoon run, much of the Lane 5 VIP data were reported as good by the170 computer as shown in Table J-11. In the Jamboree Road morning runs that are discussed in later sections, the Lane 5 VIP data were generally not reported as being reliable. In order to allow comparisons among the morning and afternoon Jamboree Road evaluations, the data summaries that appear later in this section include tabulations for two sets of “all lane” good data. The first set for Lanes 1, 3, and 4 is used to compare with the morning runs, and the second set that includes Lanes 1, 3, 4, and 5 is used for comparisons among the afternoon sets. The Lane 2 ILDs were malfunctioning during this run as noted in Table J-12. Lane 1 and Lane 3 through 5 data in Figures J-36 and J-38 through J-40, respectively, show that the ILD and VIP lane occupancies and volumes generally track one another over time. There appears to be a greater difference between the lane volumes between 15:15 and 16:15 hours than during later portions of the run.

Figure J-41 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another. Figure J-42 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The average occupancies in Figure J-42a are not very different when the Lane 5 data are included in the combined average. Figure J-43 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The percent difference between ILD and VIP volume measurement for Lane 5 (the lane closest to the surveillance trailer and camera) is smallest, equal to -32.4 (indicating moderate VIP overcounting). The Lane 5 percent difference for occupancy is 14.1, also the smallest value in the data set. The inclusion of Lane 5 data did not significantly change the percent difference between ILD and VIP volume measurements (-46.4 versus -49.8), but had more of an impact on occupancy measurements (-8.6 versus -21.0).

4.9.7 Jamboree Road AM Rush Hour Occupancy and Volume Data for 3/12/98

Figures J-44 to J-48 compare the Jamboree Road lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 of the I-5 mainline for the 6:15 to 9:30 morning rush hours on March 12, 1998. The 170 computer that processed the VIP detector inputs reported a malfunction during the acquisition or processing of most of the Lane 5 VIP data as shown in Table J-13. The Lane 5 ILD data in Table J-14 appear proper during the recording interval. The 170 computer did not process Lane 2 ILD data, apparently because the Lane 2 inductive loops were malfunctioning. To avoid biasing of the results, none of the Lane 2 and Lane 5 data are included in the summary plots later in this section. Figures J-44 and J-46 through J-48 show that the ILD and VIP lane occupancies and volumes generally track one another over time.

Figure J-49 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-50 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 1, 3, and 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-51 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined. The VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes for the lanes reported. For Lane 4 (the closest lane to the trailer with good data), the percent difference in the volume measurements is -19.7 (indicating moderate VIP overcounting) and in the occupancy measurements is 14.4. Over the sum of Lane 1, 3, and 4 data, the percent difference for volume is -24.1 and that for occupancy is 15.9.

4.9.8 Jamboree Road PM Rush Hour Occupancy and Volume Data for 3/12/98

Figures J-52 to J-56 display the March 12, 1998 15:15 to 19:00-hour afternoon rush interval lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 at the Jamboree Road site. In this run, more of the Lane 5 VIP data were reported as good by the170 computer as shown in Table J-15. Therefore, the summaries that appear later in this section include tabulations for two sets of “all lane” good data, namely a set for Lanes 1, 3, and 4 to compare with the morning run, and a set that includes Lanes 1, 3, 4, and 5 to compare with other afternoon runs. The Lane 2 ILDs were malfunctioning during this run as well as seen in Table J-16. Lane 1 data in Figure J-52 show that the ILD and VIP lane occupancies and volumes generally track one another over time. The Lane 3 and Lane 4 data in Figures J-54 and J-55 exhibit some divergence after approximately 18:00 hours.

Figure J-57 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another except for some divergence after approximately 18:00 hours. Figure J-58 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The average occupancies in Figure J-58a are not very different when the Lane 5 data are included in the combined average. Figure J-59 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The percent difference between ILD and VIP volume measurement for Lane 5 (the lane closest to the surveillance trailer and camera) is smallest, equal to -10.3 (indicating small to moderate VIP overcounting). The Lane 5 percent difference for occupancy is 24.0, which is not the smallest value in this data set. In this run, Lane 3 had the smallest occupancy percent difference equal to -5.7. The inclusion of Lane 5 data did not significantly change the percent difference between ILD and VIP volume measurements (-34.8 versus -31.4), but had more of an impact on occupancy measurements (-8.2 versus -0.4).

4.9.9 Jamboree Road AM Rush Hour Occupancy and Volume Data for 3/13/98

The March 13, 1998 Jamboree Road lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 of the I-5 mainline are compared in Figures J-60 to J-64 as a function of time for the 6:15 to 9:45 morning rush hours. The 170 computer that processed the VIP detector inputs reported a malfunction during the acquisition or processing of most of the Lane 5 VIP data as shown in Table J-17. The Lane 5 ILD data in Table J-18 appear proper during the recording interval. Similarly, the 170 computer did not process Lane 2 ILD data, apparently because the Lane 2 inductive loops were malfunctioning. To avoid biasing of the results, none of the Lane 2 and 5 data are included in the summary plots later in this section. Figures J-60 and J-62 through J-64 show that the ILD and VIP lane occupancies and volumes generally track one another over time.

Figure J-65 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-66 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 1, 3, and 4 combined (the lanes reporting good data for both the ILDs and VIP). Figure J-67 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined. The VIP occupancies have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes for the lanes reported. For Lane 4 (the closest lane to the trailer with good data), the percent difference in the volume measurements is -26.6 (indicating moderate VIP overcounting) and in the occupancy measurements is -6.5. Over the sum of Lane 1, 3, and 4 data, the percent difference for volume is -24.5 and that for occupancy is 0.1.

4.9.10 Jamboree Road PM Rush Hour Occupancy and Volume Data for 3/13/98

Figures J-68 to J-72 display the March 13, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5, respectively, of the I-5 mainline at the Jamboree Road site. These data were acquired from 15:15 to 19:00 hours. In this run, more of the Lane 5 VIP data were reported as good by the170 computer as shown in Table J-19. Therefore, the summaries that appear later in this section include tabulations for two sets of "all lane" data, namely Lanes 1, 3, and 4 to compare with the morning run, and Lanes 1, 3, 4, and 5 to compare with the afternoon runs. The Lane 2 ILDs were malfunctioning during this run as seen in the Table J-20 data. The Lane 1 data in Figure J-68 show that the ILD and VIP lane occupancies and volumes generally track one another over time. The Lane 3 and Lane 4 data in Figures J-70 and J-71 exhibit some divergence after approximately 18:00 hours.
Figure J-73 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another except for some divergence after approximately 18:00 hours. Figure J-74 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The average occupancies in Figure J-74a are not very different when the Lane 5 data are included in the combined average. Figure J-75 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1, 3, and 4 combined and Lanes 1, 3, 4, and 5 combined. The percent difference between ILD and VIP volume measurement for Lane 5 (the lane closest to the surveillance trailer and camera) is smallest, equal to -29.6 (indicating a moderate amount of VIP overcounting). The Lane 5 percent difference for occupancy is 11.3, which is not the smallest value. In this run, Lane 1 had the smallest occupancy percent difference equal to -8.9. The inclusion of Lane 5 data did not significantly change the percent difference between ILD and VIP

volume measurements (-39.2 versus -37.8), but had more of an impact on occupancy measurements (-16.0 versus -8.7).

4.9.11 Grand Avenue AM Rush Hour Occupancy and Volume Data for 4/14/98

The April 14, 1998 Grand Avenue lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 of the I-5 mainline are compared in Figures J-76 to J-80, respectively, for the 6:15 to 9:30 morning rush hours. Most of the Lane 5 VIP data are good in this run, as shown in Table J-21. The ILD data appear in Table J-22. Figures J-76 through J-80 show that the ILD and VIP lane occupancies and volumes generally track one another over time.

Figure J-81 compares the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 2, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-82 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 1 through 4 combined and Lanes 1 through 5 combined. The average occupancies in Figure J-82a are not very different when the Lane 5 data are included in the combined average. Figure J-83 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 through 4 combined and Lanes 1 through 5 combined. The VIP occupancies over the combined lanes have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes for the combined lanes. Lane 5 has larger percent differences than do any of the other individual lanes. One explanation is that the VIP detectors in Lane 5 may not have been functioning properly as evidenced by the reporting of suspect data or a malfunction for some of the Lane 5 recording periods. The other lanes produced percent occupancy and volume differences between –12.1 and 18 (in the small to moderate range). In fact, over Lanes 1, 2, 3, and 4, the percent difference for volume averages to 12.7 (indicating small undercounting by the VIP) and that for occupancy to -4.7.

4.9.12 Grand Avenue PM Rush Hour Occupancy and Volume Data for 4/14/98

Figures J-84 to J-88 display the April 14, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5, respectively, of the I-5 mainline at the Grand Avenue site. These data were acquired from 14:45 to 19:00 hours. Table J-23 shows that all of the Lane 5 VIP data were reported as good by the170 computer. Therefore, the summaries that appear later in this section include all the data from Lanes 1 through 5. The ILD data are given in Table J-24. Figures J-84 through J-88 show that the ILD and VIP lane volumes generally track one another over time. The ILD lane occupancies are larger than the VIP-measured occupancies between about 15:00 and 16:00 hours and between about 17:00 hours and 18:00 hours.

Figure J-89 compares the average occupancy and total volume measured by the ILDs and VIP on all mainline Lanes 1 through 5 as a function of time. As in the individual lane plots, the ILD and VIP volumes track one another, but the occupancy plot shows some divergence between about 15:00 and 16:00 hours and between about 17:00 hours and 18:00 hours. Figure J-90 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data are shown for each lane and for Lanes 1 through 5 combined. There is not much difference between the individual lane values and the combined values of the occupancies. Figure J-91 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 through 5 combined. The percent difference between ILD and VIP volume measurement for Lane 5 (the lane closest to the surveillance trailer and camera) is smallest, equal to 2 (indicating a very small VIP undercount). The Lane 5 percent difference for occupancy is 28.4, the smallest value for all the lanes monitored.

4.9.13 Grand Avenue AM Rush Hour Occupancy and Volume Data for 4/16/98

Figures J-92 to J-96 compare the April 16, 1998 Grand Avenue lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5, respectively, of the I-5 mainline for the 6:15 to 9:30 morning rush hours. Most of the Lane 5 VIP data are good in this run, as shown in Table J-25. The ILD data appear in Table J-26. Figures J-92 through J-96 show that the ILD and VIP lane occupancies and volumes generally track one another well over time.

Figure J-97 displays the average occupancy and total volume measured by the ILDs and VIP on mainline Lanes 1, 2, 3, and 4 as a function of time. The two sets of ILD and VIP values track one another well. Figure J-98 contains the averages of the lane occupancy and total volume reported by the ILDs and VIP during the morning rush hour interval. Data are shown for each lane and for Lanes 1 through 4 combined and Lanes 1 through 5 combined. The average occupancies in Figure J-98a are not very different when the Lane 5 data are included in the combined average. Figure J-99 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 through 4 combined and Lanes 1 through 5 combined. The VIP occupancies over the combined lanes have a smaller percent difference with respect to the ILD occupancies, than do the VIP lane volumes compared with the ILD lane volumes for the combined lanes. Lane 5 has larger percent differences than do any of the other individual lanes. One explanation is that the VIP detectors in Lane 5 may not have been functioning properly as evidenced by the reporting of suspect data or a malfunction for some of the Lane 5 recording periods. The other lanes produced moderate percent occupancy and volume differences between –16.1 and 17.6. These are comparable to the values obtained in the April 14 run. In fact, over Lanes 1, 2, 3, and 4, the percent difference for volume averages to 11.3 (indicating small undercounting by the VIP) and that for occupancy to -3.7.

4.9.14 Grand Avenue PM Rush Hour Occupancy and Volume Data for 4/16/98

Figures J-100 to J-104 display the April 16, 1998 afternoon rush hour lane occupancies and volumes measured by the ILDs and VIP in Lanes 1 through 5 of the I-5 mainline at the Grand Avenue site. These data were acquired between 16:30 and 19:00 hours. Table J-27 shows that all of the Lane 5 VIP data in this run were reported as good by the170 computer. Therefore, the summaries that appear later in this section include all the data from Lanes 1 through 5. The ILD data are given in Table J-28. Figures J-100 through J-104 show that the ILD and VIP lane volumes generally track one another over time. The ILD lane occupancies are larger than the VIP-measured occupancies between about 17:30 hours and 18:30 hours. This same effect was seen in the April 14 data.

Figure J-105 compares the average occupancy and total volume measured by the ILDs and VIP for Lanes 1 through 5 combined as a function of time. As in the individual lane plots, the ILD and VIP volumes track one another, but the occupancy plot shows some divergence between about 17:30 hours and 18:30 hours. Figure J-106 displays the averages of the lane occupancy and total volume reported by the ILDs and VIP. Data appear for each lane and for Lanes 1 through 5 combined. There is not much difference between the individual lane values and the combined values of the occupancies. Figure J-107 shows the percent difference between the ILD and VIP averages of the average occupancy and total volume for each lane and over Lanes 1 through 5 combined. The percent difference between ILD and VIP volume measurement for Lane 4 is smallest in this run equal to 2.2 (indicating a very small VIP undercount). The Lane 5 percent difference for occupancy is 26.0, the smallest value for all the lanes monitored. The Lane 5 difference for volume is 7.8, indicating a small VIP undercount.

4.9.15 Summary of Mainline Occupancy and Volume Measurements

Table 4-11 summarizes the percent differences between the ILD and VIP total volume and average occupancy measurements for the runs made at each evaluation site. The data shown are over all lanes reporting good data. For Tustin Ranch Road, the good lanes were Lanes 2 through 4; for Jamboree Road, Lanes 1, 3, and 4; and for Grand Avenue, all lanes (Lanes 1 through 5). The Grand Avenue site had the smallest percent differences between ILD and VIP-measured mainline volumes. In morning runs the VIP undercounted at Grand Avenue, while in afternoon runs it overcounted. Additional data can be acquired to establish if there is significance to this pattern. (One potential explanation may be the presence of shadows in the afternoon.) By contrast, the VIP overcounted during both the morning and afternoon runs at the Tustin Ranch Road and Jamboree Road sites.

Table 4-11. Percent differences between ILD and VIP volumes and occupancies by evaluation site and time of day

Site	Time	Date	% Difference in Volume	% Difference in Occupancy
Tustin Ranch Road[1]	AM	3/5/98	-44.4	-10.8
	AM	3/9/98	-50.0	-10.3
	PM	3/9/98	-50.6	-53.2
	AM	3/10/98	-48.6	-10.8
	PM	3/10/98	-53.0	-49.4
Jamboree Road[2]	PM	3/11/98	-49.8	-21.0
	AM	3/12/98	-24.1	+15.9
	PM	3/12/98	-34.8	-8.2
	AM	3/13/98	-24.5	+0.1
	PM	3/13/98	-39.2	-16.0
Grand Avenue[3]	AM	4/14/98	+13.8	-1.2
	PM	4/14/98	-14.8	+34.1
	AM	4/16/98	+12.3	-4.2
	PM	4/16/98	-8.1	+27.1

1. Tustin Ranch Road data are for Lanes 2 through 4.
2. Jamboree Road data are for Lanes 1, 3, and 4.
3. Grand Avenue data are for Lanes 1 through 5.

Table 4-12a and Table 4-12b contain the average and standard deviation of the lane occupancies and volumes measured in the seven morning and seven afternoon runs by the ILDs and VIP. Table 4-12a shows the values for Lanes 1 through 3. Table 4-12b shows the values for Lanes 4 and 5 and the combination of all lanes reporting good data.

Table 4-12a. Average and standard deviation of occupancies and volumes as measured by the ILDs and VIP over Lanes 1 through 3 at all the evaluation sites

Statistic	Lane 1				Lane 2				Lane 3			
	ILD Occ	VIP Occ	ILD Vol	VIP Vol	ILD Occ	VIP Occ	ILD Vol	VIP Vol	ILD Occ	VIP Occ	ILD Vol	VIP Vol
Average	19.0	17.3	396	476	21.2	20.9	446	564	18.8	18.7	381	512
Std Dev	10.2	5.6	78	62	10.6	4.9	75	143	9.9	5.2	58	116

Table 4-12b. Average and standard deviation of occupancies and volumes as measured by the ILDs and VIP over Lanes 4 and 5 and the combination of all lanes reporting good data at all the evaluation sites

Statistic	Lane 4				Lane 5				All Lanes			
	ILD Occ	VIP Occ	ILD Vol	VIP Vol	ILD Occ	VIP Occ	ILD Vol	VIP Vol	ILD Occ	VIP Occ	ILD Vol	VIP Vol

Average	17.4	16.3	372	465	14.2	10.9	317	325	18.1	17.8	1336	1676
Std Dev	9.3	4.9	68	121	7.1	5.2	45	48	9.2	5.1	334	278

Figures 4-22 and 4-23 display the averages of the ILD and VIP-measured mainline occupancy and volume data in graphical form. The numbers near the bars are the average values that appear in Table 4-12.

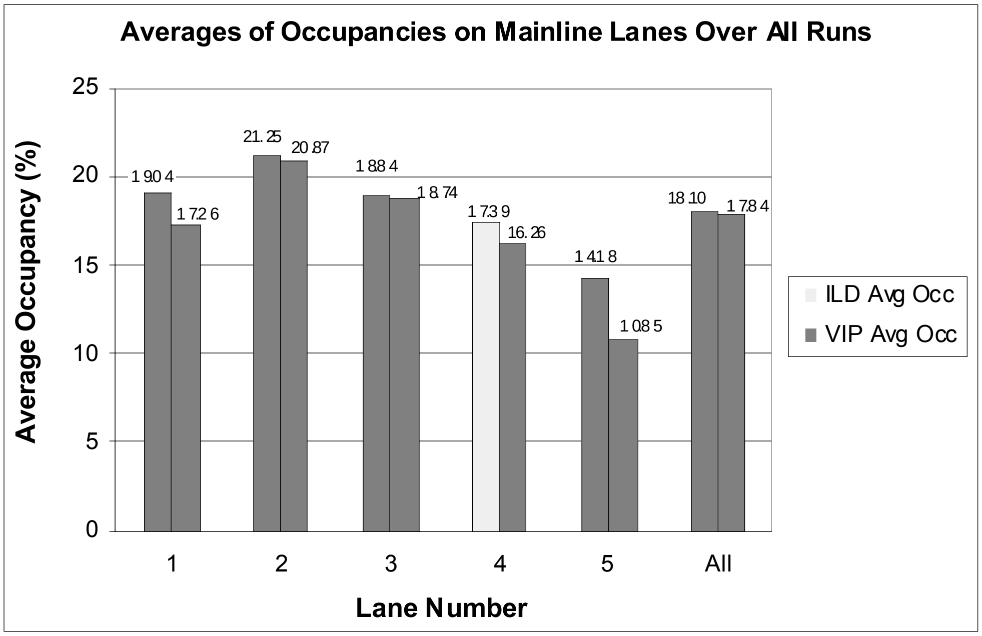

Figure 4-22. Average mainline occupancies over all runs as measured by the ILDs and VIP

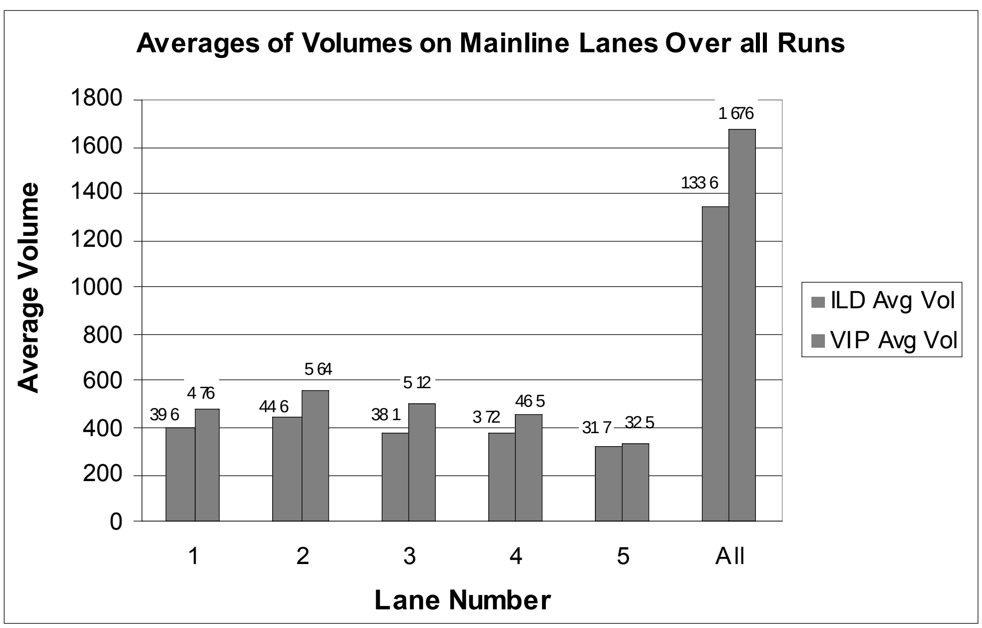

Figure 4-23. Average mainline volumes over all runs as measured by the ILDs and VIP

Figure 4-24 shows the averages of the percent differences between the ILD and VIP-measured average lane occupancies and total volumes for the fourteen runs. Lane 5, the lane closest to the shoulder, had the smallest percent difference in measured volume equal to –2.6 percent. The negative sign indicates that the VIP counted more vehicles than the ILD. Lane 3 had the smallest difference in occupancy measurement equal to 0.5 percent. The average percent differences in occupancy and volume over all lanes reporting good data were 8 and -22, respectively. The ability of the VIP to provide data with sufficient accuracy for the ramp-metering function is discussed in Section 4.10.

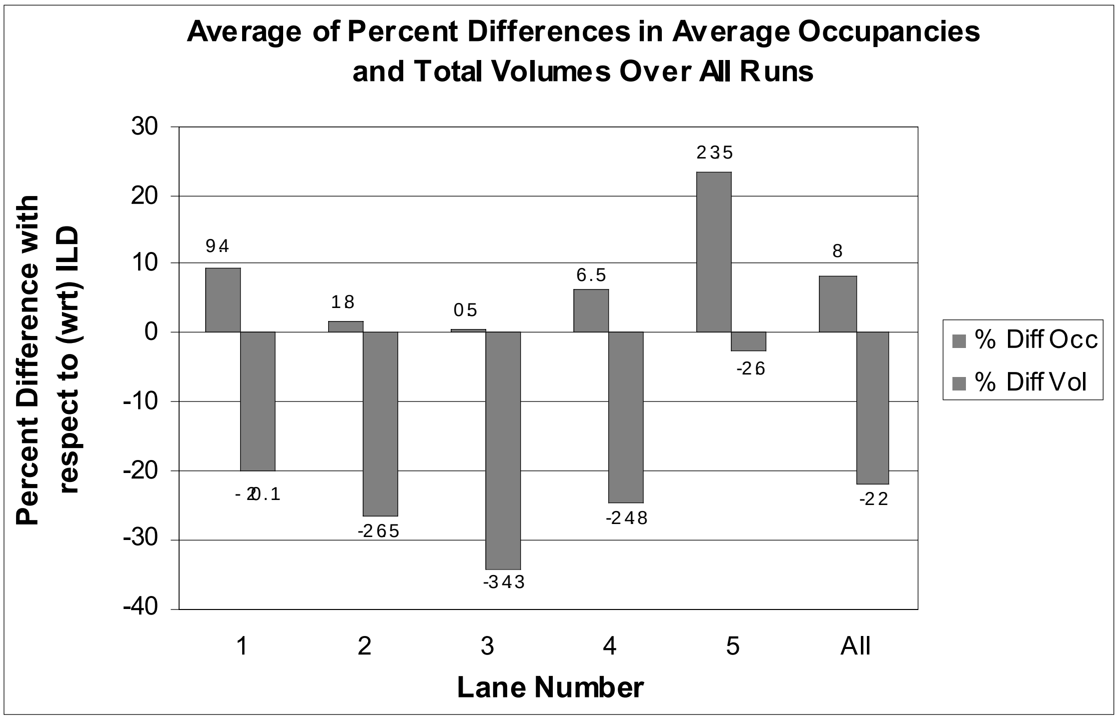

Figure 4-24. Average of the percent difference between the average occupancies and total volumes over all runs as measured by the ILDs and VIP

4.9.16 AutoScope Measurement Accuracy With More Ideal Camera Mounting

When the camera supplying imagery to the AutoScope is mounted over the center of a roadway at a minimum of 30 feet (9.1 meters) or at the side of a roadway at heights of 50 to 60 feet (15.2 to 18.3 meters), the volume, occupancy, and speed measurement accuracies are greater and, generally, meet the manufacturer's specifications shown in Table 4-13.[8,9,10]

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8. AutoScope Consultant's Designer Guide, Econolite Control Products, Anaheim, CA.
9. Detection Technology for IVHS Final Report, Lawrence A. Klein, Principal Investigator, Hughes Aircraft Company, FHWA Report Number FHWA-RD-95-100, July 1995.
10. Field Test of Monitoring of Urban Vehicle Operations Using Non-Intrusive Technologies Final Report, MnDOT, FHWA Report Number FHWA-PL-97-018, May 1997.

Table 4-13. AutoScope measurement accuracies under more ideal camera mounting

Lane Occupancy Error	Volume Flow Range and Error	Speed Range and Error	Mounting Height and Details
Not specified by manufacturer. Some measured data available that indicate ≈1-3% errors under ideal conditions.	≤ 4% day and night with centered, high camera without occlusion. <7% with artifacts such as shadows, fog, rain, snow.	Not specified. Experience shows ± 7% when measuring speed of an individual vehicle, ± 1% when measuring speed over a 15-minute interval.	30 ft (9.1 m) minimum for side-mounted camera. Monitoring of 6-8 lanes may require camera to be mounted over the traveled lanes. Greater height provides more accurate speed measurement and less occlusion of multiple-lane traffic flow by tall vehicles. Cameras mounted over center of lanes can be lower than side-mounted cameras.

4.10 Rush Hour Metering Rate Data Analysis

The following sections describe the metering rate and ramp demand results obtained at each morning and afternoon evaluation run at which 170-controller polling data were recorded on the laptop computers.

4.10.1 Tustin Ranch Road AM Rush Hour Metering Rate Data for 3/5/98

Figure J-108 shows results from the Tustin Ranch Road site for the morning rush hour interval on March 5, 1998. It compares the ramp meter rate used, the local responsive (LR) rate, and the TOD rate computed from the ILD and VIP measurement data. The ILD and VIP data output from the 170 controllers appear in Tables J-29 and J-30. The TOD rates in Figure J-108c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different rates. The different rates appear in the ILD and VIP TOD graph (Figure J-108c) and the ramp meter rate used graph (Figure J-108a). The ILD and VIP LR rates in Figure J-108b appear identical over most of the rush hour interval. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-109a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP value pairs for occupancy and volume track one another.

The percent differences between the ILD-computed and VIP-computed ramp demand occupancy and volume are shown in Figure J-109b. The –7 percent difference in ramp demand occupancy is in the small range, while the 1 percent difference in ramp demand volume is insignificant. The -44.4 percent difference in ILD and VIP mainline volume measurements over the combination of Lanes 2 through 4 (reported in Section 4.9.1) appears adequate for calculating local responsive ramp meter rates (from the VIP measurements) that are, for the most part, identical to the rates calculated from the ILDs.

4.10.2 Tustin Ranch Road AM Rush Hour Metering Rate Data for 3/9/98

Figure J-110 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Tustin Ranch Road site during the morning rush hour interval on March 9, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-31 and J-32. The time-of-day rates in Figure J-110c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. The different rates appear in the ILD and VIP TOD graph (Figure J-110c) and the ramp meter rate used graph (Figure J-110a). The ILD and VIP LR rates in Figure J-110b appear identical over most of the rush hour interval. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run. The VIP-calculated LR rate of 8 vehicles/minute at 6:45 is the only intermediate point at which the VIP and ILD LR rates are not the same.

Figure J-111a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP values for occupancy and volume track one another.

The percent differences between the ILD-computed and VIP-computed ramp demand occupancy and volume are given in Figure J-111b. The –15 percent difference in ramp demand occupancy is in the moderate range, while the 36 percent difference in ramp demand volume is significant. The small percent difference of 2.7 in ILD and VIP mainline volume measurements, as reported for the combination of Lanes 2 through 4 in Section 4.9.2, produces local responsive ramp meter rates (from the VIP measurements) that are, for the most part, identical to the rates calculated from the ILDs.

4.10.3 Tustin Ranch Road PM Rush Hour Metering Rate Data for 3/9/98

Figure J-112 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Tustin Ranch Road site during the afternoon rush hour interval on March 9, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-33 and J-34. The time-of-day rates in Figure J-112c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different rates. The different rates appear in the ILD and VIP TOD graph (Figure J-112c) and the ramp meter rate used graph (Figure J-112a). The ILD-produced LR rates in Figure J-112b appear erratic.

Figure J-113a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The two sets of values in the figure indicate the same trends over time.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-113b. The –31 percent difference in ramp demand occupancy is in the significant range, while the 23 percent difference in ramp demand volume is moderate. It is difficult to establish the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.4 Tustin Ranch Road AM Rush Hour Metering Rate Data for 3/10/98

Figure J-114 compares the ramp meter rate used, the LR rate, and the TOD rate computed from the ILD and VIP measurement data acquired at the Tustin Ranch Road site during the morning rush hour interval on March 10, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-35 and J-36. Examination of the time-of-day rate in Figure J-114c indicates that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD graph (Figure J-114c) and the ramp meter rate used graph (Figure J-114a). The ILD and VIP LR rates in Figure J-114b appear identical over most of the rush hour interval. The differences in LR rates at the beginning of the data-recording period are attributable to initialization and data interruptions that occur during the start of a run.

Figure J-115a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP values for occupancy and volume track one another.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-115b. The –23 percent difference in ramp demand occupancy is in the moderate range, while the 37 percent difference in ramp demand volume is significant. Even the significant –53.0 percent difference in the Lane 2 through 4 mainline volume ILD and VIP measurements, shown in Figure J-28, produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning of the run).

4.10.5 Tustin Ranch Road PM Rush Hour Metering Rate Data for 3/10/98

Figure J-116 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Tustin Ranch Road site during the afternoon rush hour interval on March 10, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-37 and J-38. The time-of-day rates in Figure J-116c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. The different rates appear in the ILD and VIP TOD graph (Figure J-116c) and the ramp meter rate used graph (Figure J-116a). The ILD-produced LR rates in Figure J-116b again appear erratic. This behavior was also observed during the afternoon run on March 9.

Figure J-117a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. In this run, there were only two data points that met this criterion.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-117b. The –18 percent difference in ramp demand occupancy and 29 percent difference in ramp demand volume are in the moderate range. Not much significance should be attributed to the ramp demand parameter calculations, however, since they are based on only two data points. It is difficult to establish the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.6 Jamboree Road PM Rush Hour Metering Rate Data for 3/11/98

Figure J-118 shows results from the Jamboree Road site for the afternoon rush hour interval on March 11, 1998. It compares the ramp meter rate used, the local responsive (LR) rate, and the TOD rate as computed from the ILD and VIP measurement data. The

ILD and VIP data output from the 170 controllers appear in Tables J-39 and J-40. The time-of-day rates in Figure J-118c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different rates. This accounts for the rate differences in the TOD plot (Figure J-118c) and most of the differences in the ramp meter rate used plot (Figure J-118a). The ILD-produced LR rates in Figure J-118b appear erratic. The same phenomenon was observed in the Tustin Ranch Road afternoon runs on March 9 and 10. The erratic behavior also appeared in the ramp meter rate used plot on March 11.

Figure J-119a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The two sets of values in the figure indicate the same trends over time.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-119b. The ILD and VIP ramp demand occupancy measurements have an insignificant -1 percent difference. It is difficult to establish the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.7 Jamboree Road AM Rush Hour Metering Rate Data for 3/12/98

Figure J-120 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Jamboree Road site during the morning rush hour interval on March 12, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-41 and J-42. Examination of the time-of-day rate in Figure J-120c indicates that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD graph (Figure J-120c) and the ramp meter rate used graph (Figure J-120a). The ILD and VIP LR rates in Figure J-120b appear identical over most of the rush hour interval. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-121a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The only data that do not track one another in Figures J-121a are the ramp demand ILD and VIP volumes indicated by the triangle and cross symbols in Figure J-121a.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-121b. The ILD and VIP ramp demand occupancy measurements have a zero percent difference. The ramp demand volume measurements yield a -18 percent difference, indicating moderate overcounting by the VIP. Even the moderate -24.1 percent difference in ILD and VIP mainline volume measurements over the combination of Lanes 1, 3, and 4, shown in Figure J-51, produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.8 Jamboree Road PM Rush Hour Metering Rate Data for 3/12/98

Figure J-122 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Jamboree Road site during the afternoon rush hour interval on March 12, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-43 and J-44. The time-of-day rates in Figure J-122c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD plot (Figure J-122c) and the ramp meter rate used plot (Figure J-122a). The ILD-produced LR rates in Figure J-122b appear erratic. The same phenomenon was observed in the Tustin Ranch Road afternoon runs on March 9 and 10.

Figure J-123a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP value pairs for occupancy and volume indicate the same trends over time.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-123b. The ILD and VIP ramp demand occupancy measurements have an insignificant 1 percent difference. The ramp demand volume measurement difference of -19 percent indicates moderate overcounting by the VIP. It is difficult to establish the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.9 Jamboree Road AM Rush Hour Metering Rate Data for 3/13/98

Figure J-124 compares the ramp meter rate used, the LR rate, and the TOD rate computed from the ILD and VIP measurement data acquired at the Jamboree Road site during the morning rush hour interval on March 13, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-45 and J-46. Examination of the time-of-day rate in Figure J-124c indicates that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD plot (Figure J-124c) and the ramp meter rate used plot (Figure J-124a). The ILD and VIP LR rates in Figure J-124b are identical between 7:00 and 8:00. The differences in LR rates at the beginning of the data-recording period are attributable to initialization and data interruptions that occur during the start of a run. Differences appear in the ILD and VIP LR rates toward the end of the run.

Figure J-125a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP values for occupancy and volume track one another.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-125b. The 4 percent difference in ramp demand occupancy is in the small range, while the -37 percent difference in ramp demand volume is significant. Even the moderate –24.5 percent difference between ILD and VIP mainline volume measurements over the combination of Lanes 1, 3, and 4 (shown in Figure J-67) is adequate to produce local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.10 Jamboree Road PM Rush Hour Metering Rate Data for 3/13/98

Figure J-126 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Jamboree Road site during the afternoon rush hour interval on March 13, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-47 and J-48. The time-of-day rates in Figure J-126c indicate that the 170 controllers connected to the ILDs and VIP were programmed with different TOD rates. This accounts for the differences seen in the TOD plot (Figure J-126c) and the ramp meter rate used plot (Figure J-126a). The ILD-produced LR rates in Figure J-126b again appear erratic. This behavior was also observed during the March 11 and 12 afternoon run at Jamboree Road and in the Tustin Ranch Road afternoon runs on March 9 and 10. This “afternoon effect” bears further investigation.

Figure J-127a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. This run produced a complete set of data for the afternoon recording interval. The ILD and VIP data indicate the same trends and, in fact, are within several percent of each other.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-127b. The –5 percent difference in ramp demand occupancy is in the small range, while the -1 percent difference in ramp demand volume is insignificant. It is difficult to gauge the effects of the ILD and VIP measurement differences in mainline volume on LR meter rate because of the erratic LR rate behavior described above.

4.10.11 Grand Avenue AM Rush Hour Metering Rate Data for 4/14/98

Figure J-128 compares the ramp meter rate used, the local responsive (LR) rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Grand Avenue site during the morning rush hour interval on April 14, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-49 and J-50. At this site, the 170 controllers connected to the ILDs and VIP were programmed with the same TOD rates (seen by the overlapping of the graphs in Figure J-128c) since a large queue was not created on the ramp during the data recording period of 6:15 through 9:15 hours. This programming also caused the ILD and VIP ramp meter rate used graphs to overlap as shown in the central portion of Figure J-128a. The ILD and VIP LR rates in Figure J-128b are identical in the middle of the run. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-129a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. This run produced a complete set of data for the morning recording interval. The ILD and VIP data indicate the same trends and, in fact, are within several percent of each other.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-129b. The ILD and VIP ramp demand occupancy measurements have a -4 percent difference. The ramp demand volume measurements yield a 3 percent difference, indicating small undercounting by the VIP. The 13.8 percent difference between ILD and VIP mainline volume measurements (reported in Figure J-83) produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.12 Grand Avenue PM Rush Hour Metering Rate Data for 4/14/98

Figure J-130 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Grand Avenue site during the afternoon rush hour interval on April 14, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-51 and J-52. At this site, the 170 controllers connected to the ILDs and VIP were programmed with the same TOD rates (as seen in Figure J-130c) because a large queue was not created on the ramp during the data recording period of 14:45 through 19:00 hours. This programming accounts for the overlapping of the ILD and VIP data in most of the ramp meter rate used plot (Figure J-130a). The ILD and VIP LR rates in Figure J-130b are identical in the middle of the run. The differences in LR rates at the beginning and end of the data-recording period are mainly attributable to initialization and data interruptions that occur during the start and end of a run. There was a spike in the VIP LR rate, however, at 18:15 hours.

Figure J-131a displays ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The two sets of values in the figure show, for the most part, the same trends over time. There is some erratic behavior in the VIP ramp demand volume as indicated by the data entries marked with a cross in Figure J-131a.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-131b. The ILD and VIP ramp demand occupancy measurements have a small -3 percent difference. The ramp demand volume measurement difference of -80 percent indicates significant overcounting by the VIP. The –14.8 percent difference in ILD and VIP-measured mainline volume over all lanes (reported in Figure J-91) produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run and the one spike at 18:15 hours).

4.10.13 Grand Avenue AM Rush Hour Metering Rate Data for 4/16/98

Figure J-132 compares the ramp meter rate used, the LR rate, and the TOD rate computed from the ILD and VIP measurement data acquired at the Grand Avenue site during the morning rush hour interval on April 16, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-53 and J-54. At this site, the 170 controllers connected to the ILDs and VIP were programmed with the same TOD rates (as seen in Figure J-132c) since a large ramp queue was not formed during the run interval of 6:15 to 9:15 hours. This programming accounts for the overlapping of the ILD and VIP data in most of the ramp meter rate used plot (Figure J-132a). The ILD and VIP LR rates in Figure J-132b are identical in the middle of the run. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-133a shows ramp demand occupancy (in percent) and volume (in vehicles/ minute) as calculated from the ILD and VIP data. This run produced a complete set of data for the morning recording interval. The ILD and VIP data indicate the same trends and, in fact, are within several percent of each other.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-133b. The 0.8 percent difference in ramp demand occupancy is insignificant, as is the –1.5 percent difference in ramp demand volume. The 12.3 percent difference in ILD and VIP-measured mainline volume over all lanes (shown in Figure J-99) produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.14 Grand Avenue PM Rush Hour Metering Rate Data for 4/16/98

Figure J-134 compares the ramp meter rate used, the LR rate, and the TOD rate as computed from the ILD and VIP measurement data acquired at the Grand Avenue site during the afternoon rush hour interval on April 16, 1998. The ILD and VIP data output from the 170 controllers appear in Tables J-55 and J-56. At this site, the 170 controllers connected to the ILDs and VIP were programmed with the same TOD rates (as seen in Figure J-134c) since a large ramp queue was not formed during the run interval of 16:30 and 19:00 hours. This programming accounts for the overlapping of the ILD and VIP data in most of the ramp meter rate used plot (Figure J-134a). The ILD and VIP LR rates in Figure J-134b are identical in the middle of the run. The differences in LR rates at the beginning and end of the data-recording period are attributable to initialization and data interruptions that occur during the start and end of a run.

Figure J-135a shows ramp demand occupancy (in percent) and volume (in vehicles/minute) as calculated from the ILD and VIP data. Only values for which both ILD and VIP data are reported as good are plotted. The ILD and VIP data indicate the same trends and, in fact, are within several percent of each other.

The percent differences between the ILD and VIP ramp demand occupancy and volume are given in Figure J-135b. The –0.2 percent difference in ramp demand occupancy is insignificant. The 4 percent difference in ramp demand volume is small. The –8.1 percent difference in ILD and VIP-measured mainline volume (shown in Figure J-107) produces local responsive ramp meter rates (from the VIP measurements) that are identical to the rates calculated from the ILDs (with the exception of the beginning and end of the run).

4.10.15 Summary Comments Concerning Rush Hour Metering Rate Data

1. The ILD-produced LR rates for the afternoon runs at the Tustin Ranch Road and Jamboree Road sites appear erratic. The same behavior was not observed during the morning runs at these sites or at the morning or afternoon runs at the Grand Avenue site. This “afternoon effect” bears further investigation.

2. The VIP data appear to be sufficiently accurate to adapt ramp meter rates to the real-time traffic volume and occupancy on the mainline. This is shown in the comparison of the LR rates produced by the ILD and VIP data. These errors were tolerable because a more restrictive metering rate (namely zero) than the prestored TOD rate was calculated by the metering algorithm from the ILD and VIP real-time data. Therefore, the algorithm reverted to the less restrictive TOD rate for both sets of data. To verify that the VIP data are sufficient to support local responsive metering, additional data should be gathered during periods of lighter mainline traffic when the local responsive algorithm will not clamp at its lower limit.

3. However, the larger percent differences between mainline volume measured by the ILDs and VIP may lead to the reporting of erroneous levels of service on the mainline. This potential problem is caused by the VIPs over estimating the volume by as much as 53 percent or under estimating it by as much as 14 percent as was shown in Table 3-6. It is more likely that the VIP will overcount when the camera is mounted as it was in this evaluation.

4.11 Qualitative Data to Evaluate Utility of Surveillance Trailer Placement in a Construction Zone

Discussions took place with Caltrans and Anaheim during the Winter and Spring of 1998 to select a construction site that would be suitable to the two agencies. Both wanted a location near a freeway interchange that was under construction. Caltrans could use the video imagery to determine traffic queues and implement flush plans to clear intersections under their control. Anaheim could use the imagery in a similar manner. The site of choice was the I-5 interchange at Katella Avenue in Anaheim. It had Disneyland and Anaheim Convention Center traffic, freeway and arterial construction, and recurring peak-hour congestion. A surveillance trailer was brought there, but before it could become operational, it had to be moved because it interfered with the contractor’s reconstruction activities. (The contractor had previously given permission to bring the trailer to this site.) It was more difficult to find a site where both a surveillance and ramp meter trailer could be situated. Three factors impacted a ramp-metering deployment. First, an analysis of traffic volume is required to find the controlling bottleneck on the freeway under construction. Ramp metering can then be applied upstream of the bottleneck. However, the survey takes personnel and monetary resources that are not readily available. Second, it is difficult to find real estate that can accommodate both trailers. This problem is exacerbated by the frequent realignment of the freeway in the construction area. Third, Caltrans prefers permanent to temporary metering devices to ensure driver acceptance and compliance.

Eventually a surveillance trailer was brought to Katella Way and I-5 as shown in Figure 4-25. The intent was to gather information about the trailer’s use in an actual construction area. The Caltrans District 12 TMC personnel periodically ensured that the cameras and their scanning controls were operational, but did not really use the video imagery in traffic operations. It is believed, however, that the imagery from the cameras would have been used if an emergency developed in the area surveilled by the cameras.

(a) Rear view of trailer showing southbound I-5 and entrance ramp

(b) Katella Way entrance ramp showing surveillance trailer to left of ramp

Figure 4-25. Surveillance trailer location at southbound entrance to I-5 at Katella Way